APTD-0733

274

PB 202 665

STATE OF THE ART: 1971

INSTRUMENTATION FOR MEASUREMENT OF PARTICULATE EMISSIONS FROM COMBUSTION SOURCES

VOLUME I: PARTICULATE MASS - SUMMARY REPORT

by

Gilmore J. Sem
John A. Borgos
John G. Olin
John P. Pilney
Benjamin Y. H. Liu
Nicholas Barsic
Kenneth T. Whitby
Frank D. Dorman

Thermo-Systems Inc.
2500 North Cleveland Avenue
St. Paul, Minnesota 55113

This report was prepared under Contract No. CPA 70-23 with the Division of Process Control Engineering, Air Pollution Control Office, Environmental Protection Agency.

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
Springfield, Va. 22151

194

A

PB-202 665

BIBLIOGRAPHIC DATA SHEET

1. Report No. APTD-0733

2.

3. Recipient's Accession No.

4. Title and Subtitle

State of the Art: 1971 Instrumentation for Measurement of Particulate Emissions From Combustion Sources Volume I: Particulate Mass-Summary Report

5. Report Date April 1971

6.

7. Author(s) Gilmore J. Sem, John A. Borgos, John C. Olin, John P. Pilney, Benjamin Y. H. Liu, Nicholas Barsic, Kenneth T. Whitby, and Frank D. Dorman

8. Performing Organization Rept. No.

9. Performing Organization Name and Address

Thermo-Systems Inc.
2500 North Cleveland Avenue
St. Paul, Minnesota 55113

10. Project/Task/Work Unit No.

11. Contract/Grant No. CPA 70-23

12. Sponsoring Organization Name and Address

Environmental Protection Agency
Air Pollution Control Office
Division of Process Control Engineering
Research Triangle Park, North Carolina 27711

13. Type of Report & Period Covered

14.

15. Supplementary Notes DISCLAIMER - This report was furnished to the Office of Air Programs by Thermo-Systems Inc., 2500 North Cleveland Avenue, St. Paul, Minnesota 55113 in fulfillment of Contract No. CPA 70-23

16. Abstracts

All known sensing techniques available for application to automatic, continuous measurement of the rate of particulate mass emissions from large fossil-fuel combustion facilities are discussed. Emphasis is on the measurement of particle mass rather than other particle parameters, and emissions downstream rather than upstream of any control equipment. Although sensors for permanently-installed effluent monitoring systems are emphasized, much of the information is also applicable to portable and research instruments. Brief surveys are presented of all known particle sensing techniques. A brief discussion of the principle of operation is followed by a list of inherent and practical strengths and weaknesses of each technique. A list of commercial manufacturers of related equipment and a list of 1,352 references helps the reader who needs more information on a specific technique. Recommendations for further development outline areas of needed improvement for techniques which offer some promise for stack monitoring. The introduction includes general comments which apply to all sensing techniques, and ranks all techniques in order of present apparent potential. A separate chapter summarizes typical conditions found in large fossil-fuel effluent gases and sets the necessary specifications for a particulate monitoring instrument which operates in an effluent gas atmosphere.

17. Key Words and Document Analysis. 17a. Descriptors

Air pollution
Measuring instruments
Particles
Exhaust emissions
Combustion products
Continuous sampling
Flue gases

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group 13B

18. Availability Statement Unlimited

19. Security Class (This Report) UNCLASSIFIED

20. Security Class (This Page) UNCLASSIFIED

21. No. of Pages ~~192~~ 194

22. Price 3.00 - .95

FORM NTIS-35 (10-70)

USCOMM-DC 40329-P71

C

STATE OF THE ART: 1971
INSTRUMENTATION FOR MEASUREMENT OF PARTICULATE EMISSIONS FROM COMBUSTION SOURCES
VOLUME I: PARTICULATE MASS - SUMMARY REPORT

by

Gilmore J. Sem
John A. Borgos
John G. Olin
John P. Pilney
Benjamin Y. H. Liu
Nicholas Barsic
Kenneth T. Whitby
Frank D. Dorman

Thermo-Systems Inc.
2500 North Cleveland Avenue
St. Paul, Minnesota 55113

This report was prepared under Contract No. CPA 70-23 with the Division of Process Control Engineering, Air Pollution Control Office, Environmental Protection Agency.

THERMO-SYSTEMS INC.

TABLE OF CONTENTS

VOLUME I

Page

FOREWORD 5

ABSTRACT 6

INTRODUCTION 8

SUMMARY OF STACK EMISSIONS PROPERTIES AND INSTRUMENT SPECIFICATIONS 11

SUMMARY OF PARTICLE SENSING TECHNIQUES 15

INDEX OF PARTICLE SENSING TECHNIQUES 17

REFERENCES 87

VOLUME II

FOREWORD 5

ABSTRACT 6

SAMPLING PROBE DESIGN 7

DISCUSSION OF MEASUREMENT TECHNIQUES

MASS SENSING TECHNIQUES:

BETA RADIATION ATTENUATION 29

PIEZOELECTRIC MICROBALANCE 43

RESONANT FREQUENCY 57

GRAVIMETRIC WEIGHING 67

ELECTROSTATIC MEASUREMENT METHODS 73

OPTICAL SENSING TECHNIQUES:

LIGHT TRANSMISSION 98

MULTI-WAVELENGTH LIGHT TRANSMISSION 115

LIGHT SCATTERING: POLARIZATION RATIO METHODS . . . 126

ANGULAR LIGHT SCATTERING 134

When U. S. Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise, or in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

References to named commercial products in this report are not to be considered in any sense as an endorsement of the product by the Government.

TABLE OF CONTENTS (continued)

Page

SOILING POTENTIAL 145

OPTICAL COUNTERS AND PHOTOMETERS 148

LIDAR 158

HOLOGRAPHY 163

MISCELLANEOUS SENSING TECHNIQUES:

ACOUSTICAL ATTENUATION AND DISPERSION 172

HOT-WIRE ANEMOMETRY 177

PRESSURE DROP IN NOZZLES 179

STACK EMISSIONS PROPERTIES AND INSTRUMENT SPECIFICATIONS . . 181

BLANK PAGE

FOREWORD

The compilation of the information contained in this publication was performed pursuant to Contract 70-23 with the Air Pollution Control Office, Environmental Protection Agency.

The information was compiled by Thermo-Systems Inc., and their subcontractor, North Star Research and Development, during the period 12 February 1970 to April 1971.

Volume I of this report is written for the engineer or planner who needs to know a few basic facts about a particulate mass measurement technique and wishes to minimize the time required to obtain this information. Volume I is intended for use as a quick reference guide.

Volume II of this report is designed as a detailed in-depth report on operating principles, techniques, historical data, and discussion of the more viable techniques for particulate mass monitoring. Volume II is designed for the plant engineer, abatement and control officials, and others who may not be familiar with the detailed technology of these areas. Included are sections on power plant emissions properties and extraction sampling probes.

Volume III of this report is a comprehensive survey of particle sizing techniques which may be used by the plant engineer, abatement and control officials, and others as a quick reference guide or as a source of more detailed information, including references to original work.

Volume IV of this report describes an experimental evaluation of the beta radiation attenuation and piezoelectric microbalance techniques for mass concentration measurements on a coal-fired power generating plant. Problem areas requiring further development are identified for personnel concerned with improving the techniques.

This report is reviewed and approved.

F. C. Jaye
Project Officier
Environmental Protection Agency

ABSTRACT AND CONCLUSIONS

This report discusses all known sensing techniques available for application to automatic, continuous measurement of the rate of particulate mass emissions from large fossil-fuel combustion facilities are discussed. The report emphasizes Emphasis is on the measurement of particle mass rather than other particle parameters, and emissions downstream rather than upstream of any control equipment. Although the report emphasizes sensors for permanently-installed effluent monitoring systems are emphasized, much of the information is also applicable to portable and research instruments.

Volume I (this volume) contains brief surveys are presented of all known particle sensing techniques. A brief discussion of the principle of operation is followed by a list of inherent and practical strengths and weaknesses of each technique. A list of commercial manufacturers of related equipment and a list of 1352 references helps the reader who needs more information on a specific technique. Recommendations for further development outline areas of needed improvement for techniques which offer some promise for stack monitoring. The introduction includes general comments which apply to all sensing techniques, and ranks all techniques in order of present apparent potential. A separate chapter summarizes typical conditions found in large fossil-fuel effluent gases and sets the necessary specifications for a particulate monitoring instrument which operates in an effluent gas atmosphere.

Volume II contains detailed discussions of particle sensing techniques as applied to emissions monitoring. Each discussion analyzes possible problems, and their solutions, in using the technique for emissions monitoring, and includes an analysis of what particulate parameter the technique senses, how closely the measurement correlates with particulate mass, inherent measurement errors, practical design problems and possible solutions, the potential sensitivity and response of each technique, the complexity of the potential instrument, the present state of development of the technique, and recommendations for further development. Each discussion includes a complete bibliography. A separate chapter describes typical conditions found in large fossil-fuel effluent gases in greater detail than found in Volume I. Another separate chapter summarizes many of the problems encountered in the design of sampling probes required by most of the particle sensing techniques.

Accurate measurement of the particulate mass emissions rate requires an instrument which directly senses the true mass of the particles. Sensors that are not sensitive to particulate mass, even though they may be calibrated against a mass sensor, do not and cannot yield satisfactory correlation with particle mass emissions during periods of changing and/or abnormal plant operating conditions. Effluent characteristics, such as particle size and density, change often in stacks. This may be a result of changes in combustion efficiency, fuel composition, collector performance, or other system variables.

All existing mass sensors require at least partial extraction of a representative effluent sample from the stack. No present commercial mass sensors meet the requirements for accurate, long-term, continuous monitoring. Two techniques could probably be developed into next-generation commercial stack monitors within 1 - 3 years: beta radiation attenuation and piezoelectric microbalance. Beta radiation attenuation has been partially developed for stacks with several first-generation commercial instruments available. These instruments appear to need design improvements. First-generation piezoelectric microbalance instruments exist for ambient air monitoring, but no stack monitoring development has been done.

Optical, or light, transmission is presently the most commonly used particulate monitoring technique. It measures the optical density of stack effluents very accurately if the instrument is carefully designed. Unfortunately, few of the presently available transmissometers are well-designed for accurate long-term optical density measurements. Although light transmission offers several significant instrument design advantages, the measurement does not correlate well with particulate mass measurement, especially during changing effluent conditions.

Volume III contains discussions of automatic or semi-automatic particle size measuring techniques as applied to emissions monitoring. The dicussions emphasize the particulate parameter (mass, number, surface area, etc.) which each technique senses as well as the method of classifying particles into size ranges (aerodynamically, electrostatically, optically, etc.). Included are major features of each technique, including practical problems which may be encountered when applying the technique to effluent streams. Also included is a brief, but comprehensive, survey of the many methods of expressing particle size, and an evaluation of which are most useful for effluent particles.

Volume IV is the final report containing preliminary results of an experimental evaluation of the beta radiation attenuation technique and the piezoelectric microbalance technique. Most of the experimental work was performed on an effluent duct of a large coal-fired power generating plant. The experimental sampling system and the method of evaluation are described.

INTRODUCTION

Measurement of the total mass flow of particulate emissions from large combustion facilities is a major problem facing plant owners, pollution control officials, and emission control equipment manufacturers. Plant owners need such measurements to more carefully control the combustion and air pollution control efficiency of the facility. Pollution control officials need permanent records of stack mass emissions to aid in air pollution abatement. Emission control equipment manufacturers need more efficient ways to evaluate the performance of their equipment. Instrumentation that automatically and continuously records particulate mass emissions is rapidly gaining importance as a desirable tool to accomplish these goals.

In the past, particulate emissions measurements have been made by sampling a known volume of effluent gas through a filter, and weighing the filter before and after sampling to find the particle mass concentration. By traversing the effluent gas stream cross-section to measure gas velocity as well as to obtain the filter samples, an estimate of the total mass of particles emitted per hour could be made. Such measurements require considerable equipment, labor, and time. One series of measurements typically takes about four hours with perhaps three additional man-days of labor for planning, equipment transport, setup, sampling, and data reduction. This method cannot be used economically on a regular basis for measuring combustion efficiency, for monitoring pollutant emissions, or for extensively evaluating pollution control equipment.

Thus, the emphasis of this report is on automatic and continuous monitors of particulate mass emissions. Automatic means that the instrument is capable of unattended operation for extended periods of time, at least 24 hours, but preferably more than a week. Continuous means that measurements are either made instantaneously in real time, or measurements are made with a frequency great enough for most practical monitoring purposes. A measurement every few minutes is probably sufficient for monitoring pollutant emissions while nearly instantaneous measurements may be needed for some evaluations of pollution control equipment. Often, a gain in the speed with which a measurement can be made results in a sacrifice in accuracy.

The primary goal of this discussion is to define the relative merits of particle-sensing instruments with regard to the measurement of particulate mass or mass concentration. Notice that the emphasis is on the direct measurement of mass, not some other particle parameter. Any instrument which measures some other form of particle concentration, whether it is number, area, or some other parameter, can be calibrated to read mass concentration under specific conditions. However, if those specific conditions change, the mass calibration is no longer valid and inaccurate measurements result. Parameters such as the size distribution and specific gravity of emissions particles can, and do, change drastically with minor changes in combustion efficiency or coal composition within a specific facility. Therefore, instruments which do not directly sense particle mass, or a parameter closely related to mass, must be severely discounted for reliable mass emissions measurement. In the following discussions of measurement techniques, special emphasis is given to the parameter of the particles which each technique measures.

Particle sensing techniques have many monitoring applications ranging from clean rooms to pneumatic conveying systems. Only a few of the techniques are applicable to the sensing of particles in effluent gas streams from combustion sources. Fewer yet are applicable to the sensing of particulate mass in such streams. The measurement of primary interest from a pollution standpoint is the particulate mass flow rate, i.e., the total mass of particles leaving the stack per hour. Most particulate mass sensors, on the other hand, measure particle concentration in terms of the mass of particles per unit of gas volume. This discussion assumes that the measurement of particulate mass concentration is sufficient to define particulate mass flow rate. The volumetric gas flow rate must be measured separately or estimated from the operating conditions of the process.

A complete particulate mass concentration monitoring system generally consists of three components: a sampling system, a sensing system, and a data processing and recording system. The subject of this report is the sensing system. Data processing and recording is only discussed in cases where it becomes significantly simpler or more complicated than usual.

The sampling system, including the nozzle, probe, and sample conditioner, usually contributes as much to the measurement error as the sensing system. The design of an optimum sampling system is a difficult problem. Indeed, at the present time, sampling systems are a highly controversial subject. The brief report on sampling probe design included in Volume II of this report does not pretend to be complete, but does introduce many of the problems encountered in designing such a system.

Several particulate emissions monitoring systems consist of only two major components: a sensing system and a data processing and recording system. They do not require a sampling system with its accompanying measurement errors. As will be seen later, however, all of the techniques which do not need a sampling system have other problems which may result in even greater errors in the measurement of particulate mass.

There is a question about the relative merits of integrated versus point measurements of particle concentration. The most commonly used particle monitors, light transmissometers, are integrating instruments. They measure the average particle concentration along the measuring path. Most other potential and existing particle monitoring instrument measure the particle concentration at a point within the duct. If the gas velocity and particle concentration profiles are relatively homogeneous across the duct, either integrated or point sampling can yield good results with little trouble. However, such conditions seldom exist. Not only is the gas velocity profile usually skewed, but the particle concentration profile may be skewed in a different way. Thus, in general, it is not clear which sampling method will result in the most representative measurement. Each specific situation must be analyzed in detail. One conclusion is certain, however: the placement of any instrument within an effluent duct must be done carefully so that a representative measurement is made.

The operating environment strongly affects the application of any instrument for measuring particulate emissions. A separate chapter defines typical effluent gas stream conditions for large, modern, fossil-fuel combustion facilities. The data was obtained through an extensive survey of the open literature and private reports. There is a rather severe lack of detailed information about emissions from combustion sources, primarily caused by the difficulty in making the measurements. The information about effluent gas conditions was used to define a set of desirable instrument specifications for monitoring particulate effluents. A more detailed description of effluent gas streams is included in Volume II of this report.

Since the effluent from oil combustion facilities is relatively free of particles and since only about 10% of the electric power in the U. S. is generated by such plants, the remainder of the discussion is directed primarily toward coal combustion facilities.

Particulate emissions from coal combustion facilities are usually measured in the breeching, a section of rectangular duct between the collector equipment and the vertical stack. Because the breeching is usually quite short and is seldom straight, ideal sampling conditions seldom occur. The choice of the sampling location is very important, and should be considered carefully whenever emissions measurements are made. In most cases, the accuracy of the measurement depends as much on the representativeness of the sample as on the accuracy of the sensor.

Particulate emissions are usually not measured in the vertical stacks for several reasons. In cases where several sections of breeching feed one vertical stack, measurements in the breeching allow the operator to monitor the performance of each precipitator separately. Well-developed flow conditions exist only near the top of the stack, if at all, where instrument installation is very difficult if not impossible. Most present-day instruments require regular maintenance, making installations high on a stack very inconvenient. Installation near the bottom of the stack usually has no signficant advantage over installation in the breeching. In the few instances where installation near the top of the vertical stack is convenient, such installation is definitely preferred. However, in the foreseeable future, most instruments will be installed in the breeching at a location which is a compromise between the best location from a flow consideration and the most convenient location from a consideration of installation and maintenance difficulties.

SUMMARY OF STACK EMISSIONS PROPERTIES

Table 1 summarizes the effluent characteristics from large coal- and oil-fired combustion facilities. The information presented is based upon information obtained from a search of the literature, from visits to power plants, and from discussions with the operating personnel and engineers in power plants. Obviously much more information than is presented in Table 1 is needed to define completely the environment in which a continuous mass monitoring instrument must operate. However, to obtain more and better information requires better instrumentation than now commercially available.

A list of specifications for an acceptable instrument to monitor continuously the mass emissions of particles from the stacks of large coal- and oil-fired power plants is presented following Table 1. The specifications are based upon the information presented in this section, especially that presented in Table 1, plus a knowledge of instruments and techniques that exhibit a potential for measuring mass emissions of particles in stack gases.

INSTRUMENT SPECIFICATIONS

The specifications for an acceptable instrument (permanently installed) to monitor the mass emissions of particles downstream from a control device on a large stationary coal- and oil-combustion facility are as follows:

Performance Characteristics

- Measurement must correlate with total emissions of particles into the atmosphere.
- Capability of sensing particle mass concentration in the range of 0.01 - 4.0 grams per cubic meter.
- Must cope with particulate mass concentration profiles which vary by typically ± 50 percent spatially, by a factor of 10 with time, and by a factor of 4 during sootblowing.
- Preferably senses the mass of particles from 0.01 to 300 microns. However, it would be acceptable if it senses mass from 0.1 to 50 microns for coal-firing emissions or from 0.1 to 10 microns for oil-firing emissions, which would include over 90 percent of the mass of particles.

TABLE 1 SUMMARY OF EFFLUENT CHARACTERISTICS FOR COAL AND OIL COMBUSTION

<table>
<tr><th></th><th colspan="6">COAL COMBUSTION EMISSIONS
(Controlled and uncontrolled as noted)</th><th>OIL COMBUSTION EMISSIONS
(Uncontrolled)</th></tr>
<tr><td rowspan="4">Particulate Mass Concentration</td><td>(units of grams/cubic meter)*</td><td>Before Collector</td><td>After Collector</td><td colspan="3"></td><td rowspan="4">Typical: 0.06 - 0.2
Range: 0.02 - 1.0</td></tr>
<tr><td>Pulverized fired</td><td>2.0 - 15.0</td><td>0.03 - 4.0</td><td colspan="3"></td></tr>
<tr><td>Stoker fired</td><td>0.2 - 10.0</td><td>0.06 - 3.0</td><td colspan="3"></td></tr>
<tr><td>Cyclone fired</td><td>0.4 - 4.0</td><td>0.03 - 1.0</td><td colspan="3"></td></tr>
<tr><td>Mass Concentration Variations:</td><td colspan="6"></td><td></td></tr>
<tr><td>Spatially across duct</td><td colspan="6">Typical: ± 50%</td><td>Typical: ± 50%</td></tr>
<tr><td>With time</td><td colspan="6">No information available</td><td>As much as 10-fold increase over typical</td></tr>
<tr><td>During sootblowing</td><td colspan="6">No information available</td><td>About 4-fold increase over typical</td></tr>
<tr><td rowspan="5">Particle Size</td><td>(units of microns diameter)</td><td colspan="3">Before Collector</td><td colspan="2">After Collector</td><td rowspan="5">Typical: 0.01 - 1.0 microns
Usually uncontrolled</td></tr>
<tr><td></td><td>Rg. of MMD**</td><td>5% of Mass less Than</td><td>95% of Mass Less Than</td><td>Mech. 95% of Mass Less Than</td><td>Elect. 95% of Mass Less Than</td></tr>
<tr><td>Pulverized fired</td><td>7-20</td><td>1.0</td><td>70</td><td>40</td><td>25</td></tr>
<tr><td>Stoker fired</td><td>15-70</td><td>2.0</td><td>100</td><td>40</td><td>25</td></tr>
<tr><td>Cyclone fired</td><td>3-10</td><td>1.0</td><td>50</td><td>40</td><td>25</td></tr>
<tr><td>Extreme particle size range</td><td colspan="6">0.01 - 300 microns diameter</td><td>0.01 - 40 microns diameter</td></tr>
<tr><td>Particle specific density</td><td colspan="6">0.5 - 10.0 gm/cm^3 (variable within each stack)</td><td>0.5 - 5.0 range (variable within each stack)</td></tr>
<tr><td>Flue gas velocity</td><td colspan="6">Range: 30 - 120 fps Average: 50 - 60 fps
Average velocity fluctuates less than ± 3 fps in most stacks</td><td>Range: 30 - 120 fps Average: 50 - 60 fps
Average velocity fluctuates less than ± 3 fps in most stacks</td></tr>
<tr><td>Flow condition</td><td colspan="6">Turbulent and nonuniform</td><td>Turbulent and non-uniform</td></tr>
<tr><td>Periodicity of flow fluctuations</td><td colspan="6">30 - 120 cycles per minute</td><td>30 - 120 cyles per minute</td></tr>
<tr><td>Flue gas temperature</td><td colspan="6">Range: 270 - 400°F Typical 290-330°F (varies less than ± 5°F in most stacks)</td><td>Typical: Slightly higher than coal-fired</td></tr>
<tr><td>Dew point of flue gases</td><td colspan="6">Water: <140°F Acid: 220 - 270°F</td><td>No quantitive information available</td></tr>
<tr><td>Moisture content of flue gas</td><td colspan="6">5 - 10% by volume</td><td>No information available</td></tr>
<tr><td>Existing sampling port size</td><td colspan="6">3 - 8 inch I.D. hole typical</td><td>3 - 8 inch I.D. hole typical</td></tr>
<tr><td>Distance across duct from port</td><td colspan="6">Range: 5 - 30 ft. Typical: 7 - 15 ft.</td><td>Range: 5 - 30 ft. Typical: 7 - 15 ft.</td></tr>
<tr><td>Static pressure at sampling ports</td><td colspan="6">Range: 5" positive to 15" negative water pressure
Typical: 0" to 10" negative water pressure</td><td>No information available</td></tr>
</table>

*1 grain/cubic foot = 2.29 grams/cubic meter

**MMD = mass median diameter of the particle size distribution

- Reproducibility between two identical instruments of ± 20%.
- Calibrated accuracy of ± 30%.
- Should record such items as zero and span every 1 to 6 hours on data recordings.
- Preferably have an instantaneous readout of the total mass of particles emitted into the atmosphere per unit time, or at least one average readout every 15 minutes.
- Outputs compatible with standard strip chart or digital recorders and with computer data inputs.

Environmental Requirements

- Operate with flue gas velocities of 30 to 120 feet per second.
- Operate in a variety of stacks, each having widely different velocity profiles.
- Not adversely affected by turbulent flow with characteristic eddy dimensions of 6 inches to 6 feet.
- Operate with flue gas temperatures ranging from 250 to 400°F and with temperature fluctuations of ± 5°F for short range periods (less than 1 day) and of ± 20°F for long range periods (more than 1 day).
- Operate in corrosive flue gas containing sulfur trioxide, both combined and uncombined.
- Must not restrict the flue gas flow in any significant way.
- Must withstand such environmental conditions as vibration with amplitudes as high as 1/2 inch and frequencies on the order of 0.1 - 1.0 Hz, all types of meteorological conditions, and direct sunlight.
- Must operate with flue gas static pressures from 15" negative to 5" positive water pressure (atmosphere reference), and with fluctuations of ± 3" water pressure.

Maintenance and Operational Considerations

- Rugged enough to last several years without major repair.
- Little or no maintenance except for regular weekly maintenance and for major maintenance only during regular power plant maintenance shutdowns (usually every 6 months).
- Little or no calibration or adjustment while in operation.
- Easily accessible during and after installation for weekly maintenace and for calibration or adjustments.
- Easy for plant operators to understand, operate, and to make minor repairs.
- Operate on 110V or 220V, 60 Hz electrical power and requires little power, preferably no more than 1500 watts.
- May use up to 10 scfm of 90 psig compressed air in many facilities.

Economic Factors

- Installs easily within a week by 2 men in present and future stacks with little stack modifications other than holes, flanges, and utilities.
- Preferably cost $10,000 or less but definitely not more than $20,000.
- Power industry personnel must be willing to buy it.

SUMMARY OF PARTICLE SENSING TECHNIQUES

This section briefly describes a number of particle sensing techniques. Some are more applicable to the monitoring of particulate mass emissions than others. Several techniques have been developed into commercial stack monitors while others have never before been used for particle measurements. The reader who is interested in more detail about a specific measurement technique is referred to the listed references (see complete bibliography in the back of Volume I of this report) and/or the more detailed discussion in Volume II of this report (see table of contents).

Particle measurement techniques which offer some promise for particulate mass emissions monitoring from fossil-fuel combustion sources are listed below in three categories related to the present state-of-the-art:

A. Very promising, commercial instruments exist for stacks, more testing needed:

    1. Beta Radiation Attenuation

B. Very promising, commercial instruments exist for ambient air, development for stacks needed:

    1. Piezoelectric Microbalance

C. Promising, considerably more research and/or development needed:

    1. Resonant Frequency
    2. Capacitance - Dielectric Change Technique
    3. Gravimetric Weighing
    4. Rotating Masses
    5. Capacitance-Impact Sensing

Other particle measurement techniques which cannot accurately measure particle mass emissions are listed in three categories below, not necessarily in any order:

A. Useful for measuring other particle properties in stacks as sold commercially or with minor adjustment:

    1. Electrostatic Contact Charge Transfer: Konitest

2. Light Transmission
3. Soiling Potential
4. Optical Counters and Photometers
5. Condensation Nuclei Counters
6. Collection of Particles in Liquid Suspensions

B. Potentially useful for measuring other particle properties in stacks after considerable research and development:

1. Lidar
2. Holography
3. Angular Light Scattering
4. Gas Adsorption
5. Electrostatic Ion Capture and Ion Current Attenuation
6. Electrostatic Contact Charge Transfer: Probe-In-Nozzle
7. Filter Pressure Drop
8. Alpha and Gamma Radiation Attenuation
9. Volume Measurement
10. Impact Momentum Sensing

C. Little potential for particulate concentration monitoring in stacks:

1. Acoustical Attenuation and Dispersion
2. Acoustical Particle Counter
3. Flame Photometry
4. Flame Ionization
5. Hot-Wire Anemometry
6. Radioactive Tagging and Sensing
7. Pressure Drop in Nozzles
8. Electrostatic Contact Charge Transfer: Bounce

SUMMARY OF PARTICLE SENSING TECHNIQUES

This section briefly describes a number of particle sensing techniques. Some are more applicable to the monitoring of particulate mass emissions than others. Several techniques have been developed into commercial stack monitors while others have never before been used for particle measurements. The reader who is interested in more detail about a specific measurement technique is referred to the listed references (see complete bibliography in the back of Volume I of this report) and/or the more detailed discussion in Volume II of this report (see table of contents).

Particle measurement techniques which offer some promise for particulate mass emissions monitoring from fossil-fuel combustion sources are listed below in three categories related to the present state-of-the-art:

A. Very promising, commercial instruments exist for stacks, more testing needed:

   1. Beta Radiation Attenuation

B. Very promising, commercial instruments exist for ambient air, development for stacks needed:

   1. Piezoelectric Microbalance

C. Promising, considerably more research and/or development needed:

   1. Resonant Frequency
   2. Capacitance - Dielectric Change Technique
   3. Gravimetric Weighing
   4. Rotating Masses
   5. Capacitance-Impact Sensing

Other particle measurement techniques which cannot accurately measure particle mass emissions are listed in three categories below, not necessarily in any order:

A. Useful for measuring other particle properties in stacks as sold commercially or with minor adjustment:

   1. Electrostatic Contact Charge Transfer: Konitest

INDEX OF PARTICLE SENSING TECHNIQUES

Page

MASS SENSING TECHNIQUES

BETA RADIATION ATTENUATION 18
PIEZOELECTRIC MICROBALANCE 22
RESONANT FREQUENCY 25
GRAVIMETRIC WEIGHING 27
ROTATING MASSES 29
IMPACT MOMENTUM SENSING 31
CAPACITANCE-IMPACT SENSING 33

ELECTROSTATIC TECHNIQUES

ELECTROSTATIC CONTACT CHARGE TRANSFER: KONITEST 35
ELECTROSTATIC CONTACT CHARGE TRANSFER: BOUNCE 38
ELECTROSTATIC CONTACT CHARGE TRANSFER: PROBE-IN-NOZZLE . . 40
ELECTROSTATIC ION CAPTURE AND ION CURRENT ATTENUATION . . . 42
CAPACITANCE-DIELECTRIC CHANGE TECHNIQUE 44

OPTICAL TECHNIQUES

LIGHT TRANSMISSION 46
LIDAR 50
HOLOGRAPHY 52
OPTICAL COUNTERS AND PHOTOMETERS 54
ANGULAR LIGHT SCATTERING 58
SOILING POTENTIAL 60

MISCELLANEOUS TECHNIQUES

ACOUSTICAL ATTENUATION AND DISPERSION 62
ACOUSTICAL PARTICLE COUNTER 64
ALPHA AND GAMMA RADIATION ATTENUATION 66
COLLECTION OF PARTICLES IN LIQUID SUSPENSION 68
CONDENSATION NUCLEI COUNTERS 70
FILTER PRESSURE DROP 72
FLAME IONIZATION 74
FLAME PHOTOMETRY 76
GAS ADSORPTION 78
HOT-WIRE ANEMOMETRY 80
PRESSURE DROP IN NOZZLES 82
RADIOACTIVE TAGGING AND SENSING 84
VOLUME MEASUREMENT 85

BETA RADIATION ATTENUATION

PRINCIPLE OF OPERATION

When beta particles (electrons) pass through a medium, some are absorbed and some reflected, resulting in a net reduction in the beam intensity. The reduction in beam intensity, known as beta radiation attenuation, depends statistically on the electron density of the medium. Thus, correlation of attenuation with mass depends on a constant relationship between the number of electrons per molecule (atomic number) and the mass of the molecular nucleus (atomic weight). The ratio is between 0.45 and 0.50 for essentially all elements found in coal and oil combustion effluents except hydrogen which does not contribute enough to particle mass to cause any significant error. Therefore, beta radiation attenuation is a more direct measure of particle mass than any other known technique except gravimetric weighing, vibrational weighing, and centrifugal sensing.

Instruments using this technique consist of a beta radiation source (a radioisotope) and detector. In most instruments, particles from a known volume of effluent gas are collected on a filter tape and then placed between the radiation source and detector. The difference in the count rate of the detector before and after the particles are collected is a measure of the mass of the particles. Common detectors are Geiger-Muller counters, proportional counters, scintillation counters, or semiconductor counters. Common particle collectors are filters, impactors, cyclones, electrostatic precipitators, or combinations thereof.

Beta radiation attenuation is not capable of sensing airborne effluent particles without first collecting the particles and concentrating them because gas molecules also attenuate beta radiation. Since the mass of gas molecules in effluent streams is several orders-of-magnitude greater than the corresponding mass of particles, radiation attenuation caused by suspended particles cannot be accurately separated from attenuation caused by gas molecules.

COMMERCIAL EQUIPMENT

Five companies manufacture beta radiation attenuation instruments:

Gelman Instrument Company
P.O. Box 1448
600 South Wagner Road
Ann Arbor, Michigan 48106

Research Appliance Company
Route 8 & Craighead Road
Allison Park, Pennsylvania 15101

BLANK PAGE

Verewa, Hans Ugowski & Co.
433 Mulheim an der Ruhr
Postfach 1845
Eppinghofer Strasse 92/94
West Germany

Frieseke & Hoepfner GMBH
D 8520 Erlangen-Bruck
Postfach Nr. 72
West Germany

Saphymo-Srat
51, Rue de l'Amiral Mouchez
75 Paris 13^e
France

All five use an indexing filter tape as the particle collector. A sixth company:

Environmental Research Corporation
3725 North Dunlap Street
St. Paul, Minnesota 55112

is reportedly developing a commercial beta radiation attenuation instrument using a combination cyclone-filter particle collector.

REFERENCES (See BETA RADIATION ATTENUATION in Volume II).

A. Principle of Operation: 1224, 1179, 1144, 1000, 1149, 1056, 579, 961, 991, 248, 1011, 1107, 335

B. Applications: 227, 1179, 555, 1085, 1138, 1000, 576, 225, 579, 961, 1045, 1107, 821, 705

C. Data: 1189, 1117, 1224, 1179, 555, 1085, 961, 543, 1049, 573, 248, 1107, 335, 821, 705

D. Specific Instrument Descriptions: 227, 1117, 1179, 555, 1085, 1061, 225, 1048, 248, 1107, 335, 821, 705

DISCUSSION

A. Advantages

1. Directly senses a parameter closely related to particle mass.
2. Commercially available with some stack experience.
3. Needs little calibration.

4. Appears to have capability for fair reliability during long-term use.

5. Can probably operate at high temperatures.

6. Can be used with several particle collectors giving the designer greater flexibility in developing reliable instruments.

7. Problems appear to be basically engineering problems which can be solved.

B. Disadvantages

1. Requires sampling probe and is subject to probe loss errors.

2. Requires conditioning of the sampling stream.

3. Requires particle deposition.

4. Requires an automatic advancing mechanism for the sample deposit.

5. Readout not instantaneous or continuous:
   1 data point every 1 - 15 minutes

6. Filter tape in present models needs replacement every 1 - 4 weeks.

7. Moderately expensive: ≈ $8,000 - $12,000.

8. Little reliable data has been reported although most reports are positive.

C. Recommentations for Further Development

We recommend further testing, evaluation, and accompanying development of this technique. Well designed experimental testing programs, such as described by Schnitzler, et al (Ref. 1189), will undoubtedly lead to improvements, particularly for automatic, unattended operation. The optimum particle collection system remains to be found. The relative merits of various particle sampling systems needs evaluation, e.g., sample heating versus sample dilution and mounting the sensor inside the stack rather than outside. Some question remains regarding the effects which different materials, nonuniform particle deposits, and particle size have on beta radiation attentuation. The present data readout system may not be the best way of doing the job. A type of aerosol concentrator which allows detection of the particles in their airborne state would eliminate many of the operation problems of this technique, but no such concentrator is known to the authors.

D. Conclusions

Beta radiation attenuation is presently the best technique for monitoring the mass of particulate emissions from stacks, primarily because it senses a particle parameter closely related to mass and its feasibility for stack monitoring is proven. Only the piezoelectric microbalance and the capacitance impact techniques offer as much promise for such measurements at this time. These three techniques offer the most promise for the longer-range future. Considerable testing must be done to fully evaluate the error of the beta radiation attenuation technique, but basic feasibility has been proven. At least five commercial models are now available, none of which appears to be obviously superior.

PIEZOELECTRIC MICROBALANCE

PRINCIPLE OF OPERATION

Piezoelectricity is a property of certain crystals which results in an electrical charge on certain surfaces of the crystal when the crystal becomes mechanically stressed. Conversely, a piezoelectric material becomes mechanically strained if an electrical charge is placed on certain of its crystal faces. A piezoelectric crystal, when placed in an appropriate electronic oscillating circuit, will cause the circuit to oscillate at the natural vibrational frequency of the crystal.

When foreign material adheres to the surface of a vibrating piezoelectric crystal, the natural frequency of vibration of the crystal decreases. The magnitude of the frequency change is directly proportional to the mass of the deposited foreign material. Some piezoelectric materials, such as quartz, vibrate at very precise natural frequencies, so that frequency changes of one part in ten million are significant and easily detectable. This principle has been used recently to measure the mass of aerosol particles deposited onto the sensing surface by an electrostatic precipitator or an impactor.

A piezoelectric microbalance instrument for use in stacks would consist of the sampling probe and sample conditioning system, the particle collector, the piezoelectric microbalance, a crystal cleaning system, and suitable data readout equipment. Sample conditioning would probably consist of sample line heating and/or dilution with clean, dry air to prevent condensation. An impactor or electrostatic precipitator would probably be the particle collector, the choice depending on whether or not small submicron particles must be collected. The piezoelectric microbalance includes the crystal and its oscillating circuit. The data readout system would permit recording of particle mass concentration in some convenient form.

COMMERCIAL EQUIPMENT

Two companies manufacture piezoelectric microbalance systems for use in monitoring ambient air and auto exhaust aerosols. One instrument uses an electrostatic precipitator to collect particles and heats the sampling head to prevent condensation of auto exhaust vapors:

Thermo-Systems Inc.
2500 N. Cleveland Ave.
St. Paul, Minnesota 55113

The second instrument uses an impactor which collects particles above a certain critical size:

Atlantic Research Corporation
3333 Harbor Boulevard
Costa Mesa, California 92626

Several companies manufacture piezoelectric microbalance instruments for a wide range of applications, such as dew point indication and monitoring of the thickness of evaporated or sputtered thin films.

REFERENCES (See PIEZOELECTRIC MICROBALANCE and RESONANT FREQUENCY in Volume II)

A. Principle of Operation: 244, 1221, 252

B. Applications: 244, 1223, 252, 1187

C. Data: 244, 1222, 1223, 252

D. Specific Instrument Descriptions: 244, 1222, 1223, 252, 1187

DISCUSSION

A. Advantages

1. Directly senses a parameter closely related to particle mass.

2. Highest mass sensitivity of any direct mass sensing device.

3. Needs no calibration.

4. Can be used with several particle collectors giving the designer greater flexibility in developing reliable instruments.

5. Compact sensing head.

6. Commercial ambient air samplers available from 2 domestic companies, auto exhaust samplers available from 1 company, some actual experience.

7. Offers some chance for mounting completely within the effluent gas stream eliminating several sample conditioning problems.

B. Disadvantages

1. Not yet developed or proven for stack monitoring:
   a. May not sense large particles (>20μm),
   b. May not be able to operate at stack temperatures (350°F).

2. Requires sampling probe and is subject to probe loss errors.

3. Requires conditioning of the sample stream.

4. Requires particle deposition.

5. Requires crystal cleaning with its related system complexity.

6. Readout not instantaneous or continuous:
   1 data point every 5 sec. - 5 min.

7. Moderately expensive: ≃ \$7,000 - \$12,000.

C. Recommendations for Further Development

We recomend that the feasibility of this technique for stack monitoring be established soon. Feasibility tests should include tests in stack environments with typical stack particles. If feasibility is established, we recommend immediate development of the technique into practical, commercial stack monitors. Such development should include evaluation of the optimum type of crystal sensor, the relative merits of various particle sampling and collection techniques, alternate ways of cleaning the crystal, and the optimum data readout system. The development program, and the evaluation program which must follow, should include actual stack sampling to provide conclusive data on applicability and viability.

D. Conclusions

The piezoelectric microbalance technique is potentially the best method for monitoring the mass of particulate emissions from stacks, primarily because it senses particle mass directly and it has relatively high sensitivity. However, feasibility for use in stacks must yet be established. The technique shares many of the advantages and features of the beta radiation attenuation technique, but offers much greater sensitivity and time resolution than beta radiation attenuation. The total instrument package could probably be quite small making the piezoelectric microbalance instrument especially convenient as a portable monitor used by pollution abatement personnel.

RESONANT FREQUENCY

PRINCIPLE OF OPERATION

The resonant, or natural, frequency of a vibrating spring-mass system decreases if the mass is increased. This is true of any mechanical system vibrating at its resonant frequency. Thus, the change in resonant frequency when particles are added to the system is a direct measure of the mass of the added particles. Piezoelectric microbalances, discussed in a separate report, are one subgroup of the resonant frequency technique.

COMMERCIAL EQUIPMENT

No commercial equipment using this principle is available other than piezoelectric microbalances. Very little laboratory equipment exists.

REFERENCES (See PIEZOELECTRIC MICROBALANCE and RESONANT FREQUENCY in Volume II)

A. Principle of Operation: 1228, 1239

B. Applications: 1228

C. Data: 1228

D. Specific Instrument Descriptions: 1228

DISCUSSION

A. Advantages

1. Directly senses particle mass.
2. Needs little calibration.
3. Can be used with several particle collectors.
4. Should be relatively simple to operate.
5. Should make a rugged instrument.
6. Technique is very similar to piezoelectric microbalances which are commercially available for some particulate mass monitoring applications.

B. Disadvantages

1. Almost no development of the technique has been done, feasibility not well proven.
2. Requires sampling probe and is subject to probe loss errors.
3. Requires particle deposition.
4. May require conditioning of the sample stream.
5. Requires periodic cleaning of the deposit surface.
6. Readout not instantaneous or continuous:
   Probably capable of 1 data point every 1
   second to 1 hour.
7. A possible problem is lack of required sensitivity.

C. Recommendations for Further Development

We recommend that feasiblity testing of this technique be done soon. If such tests indicate high potential for stack monitoring, we recommend further development into a practical instrument. Since this technique does measure mass and has no apparent major disadvantages, it definitely merits further investigation. If feasibility is proven, it appears that development into commercial stack monitoring instruments will take at least two years.

D. Conclusions

This technique measures mass directly and has no apparent major problems except its infant state of development. Piezoelectric microbalances, a subgroup of this technique, have proven useful for many particle mass monitoring applications. If the sensitivity of other resonant frequency devices proves high enough for stack monitoring, the technique has great promise of development into a rugged, reliable instrument in a relatively short time. Development of this technique definitely appears justified.

GRAVIMETRIC WEIGHING

PRINCIPLE OF OPERATION

A gravimetric weighing device consists of a pivot point about which two equal and opposing torques act. One torque is set up by the weight of the particle sample whose mass is to be determined. The other torque is usually controlled such that a "null" position is reached where both torques are equal. Several techniques are possible for measuring and controlling this opposing torque.

When this technique is used for measuring particle mass concentration, a means of collecting the particles is needed. The collector can be an electrostatic precipitator, an impactor, a filter, or a cyclone. The collection surface must be locked while the particles are being collected and freed when weighing is done. Air flow must be turned off or diverted during weighing to avoid disturbing the balance. A mechanism for automatic cleaning or replacing of the collection surface is needed.

COMMERCIAL EQUIPMENT

Several commercial balances exist for manual weighing of samples and most components needed for automating the technique exist. However, no commercial equipment exists using this technique to measure particle mass concentration automatically.

REFERENCES (See GRAVIMETRIC WEIGHING in Volume II)

A. Principle of Operation: 243, 1097, 938, 1096

B. Applications: 243, 225

C. Data: 243

D. Specific Instrument Descriptions: 243

DISCUSSION

A. Advantages

1. Directly senses particle mass.
2. Needs little calibration.
3. Has been tested in stack environments.
4. Can be used with several particle collectors.
5. Problems appear to be basically engineering problems which can be solved.

B. Disadvantages

1. Potential instrument appears expensive, perhaps around $12,000 - $15,000.
2. Requires sampling probe and is subject to probe loss errors.
3. Requires conditioning of the sample stream.
4. Requires particle deposition.
5. Requires an automatic advancing mechanism for the sample deposit.
6. Automatic designs require many moving parts with reliability a potential problem.
7. Sensitive to vibration.
8. Readout not instantaneous or continuous:
   1 data point every 1 - 30 minutes
9. Not available commercially.
10. Little data available on research prototype units.

C. Recommendations for Further Development

We recommend that any further development of this technique be postponed pending the results of development on the beta radiation attenuation and piezoelectric microbalance techniques. Since the feasibility of this technique seems to be proven, any further development should concentrate on engineering design of the mechanism for automating the cleaning or replacing of the collecting surface. Improvement would also seem possible in the sensing of the torque on the balance.

D. Conclusions

Gravimetric weighing is the most familiar method for directly measuring the mass of particles. However, automation of the technique leads to a system with considerable mechanical complexity with the associated problems of high cost and low reliability. For this reason, the beta radiation and piezoelectric microbalance techniques offer greater promise for the continuous monitoring of the mass of particles in effluent streams. Gravimetric weighing may find a place in research measurements of particle mass.

ROTATING MASSES

PRINCIPLE OF OPERATION

The mass of a given sample of particles can be sensed by the change in inertia which they cause when placed in a centrifuge. A sample of particles can be collected at a point on a rotating body such that a dynamic off-balance is set up, causing the body to vibrate as it rotates. The off-balance caused by the particles is a function of the mass of the collected sample, and can be detected by a displacement detector which is sensitive to the magnitude of dynamic vibrations.

A similar means of sensing particle inertia is to deposit the particles on a rotating body, apply a constant torque, and measure the angular acceleration of the body. The difference in acceleration before and after the deposit of the particle sample is a direct measurement of the angular momentum added by the particles, and, therefore, is a measurement of the mass of the particles. In this case, the particles must be deposited at a known radius from the axis of rotation, and a sensitive accelerometer must be used to measure acceleration changes.

COMMERCIAL EQUIPMENT

No commercial or laboratory equipment exists at present which uses this principle to measure particle mass concentration.

REFERENCES

This technique was suggested by K. T. Whitby in private conversations. No published information has been found.

DISCUSSION

A. Advantages

1. Directly senses a parameter closely related to particle mass.
2. Needs little calibration.
3. Can be used with several particle collectors.
4. Should be relatively simple to operate.

B. Disadvantages

1. Time resolution may be limited by the requirement of a large mass of collected particles.
2. No equipment has been developed so feasibility is not proven.
3. Requires sampling probe and is subject to probe less errors.

4. Requires conditioning of the sample stream.
5. Requires particle deposition.
6. Requires an automatic cleaning mechanism.
7. Requires tight manufacturing tolerances to provide sensitive detection of acceleration or displacement.

C. Recommendation for Development

We recommend that any further development of this technique be postponed pending the results of development on the beta radiation attenuation and piezoelectric microbalance techniques. However, development programs should be considered in the future in which instruments using this principle are built and tested. Since this technique does measure mass and the instrumentation should be simple to operate, the principle definitely merits some investigation.

D. Conclusions

This technique does measure the mass of a collected sample of particles and is definitely a promising candidate for measuring stack emissions at some time in the future. However, since no work has been done using this principle, the feasibility is not fully proven and much work will be needed to develop practical monitoring instruments. Development of this technique definitely appears justified.

IMPACT MOMENTUM SENSING

PRINCIPLE OF OPERATION

When particles strike a surface, they exchange momentum with the surface. If the velocity of all particles striking a surface is constant, the momentum exchange is directly related to the mass of the particles. This principle can be used in several ways for particulate mass concentration measurements.

When a single particle hits a piezoelectric crystal, the crystal vibrates because of the momentum transfer. The vibration causes an electrical signal in the attached circuit. The amplitude of the signal is related to the particle's initial momentum. In this system, an impactor can apply the constant velocity to the particles. Suitable electronic signal manipulation could result in an indication of particle mass concentration. Only particles above 30 microns can be sensed by this method.

If particles strike the sensing plate of a sensitive gravimetric microbalance, the plate deflects a certain distance depending on the momentum of the particles. Again, an impactor can apply constant velocity to the particles. The deflection of the sensing plate, sensed electronically, is a measure of the mass of the particles striking it. The deflection of the microbalance sensing plate caused by the air jet is a potentially major problem. This method resembles the capacitance-impact technique described separately in this report.

COMMERCIAL EQUIPMENT

No commercial instruments using this technique are known to exist. The piezoelectric impact technique has been used as a micrometeorite detector on spacecraft.

REFERENCES

Reference 2 and 252 discuss the theory of the piezoelectric momentum transducer.

DISCUSSION

A. Advantages

1. Can sense a particle parameter closely related to mass.

2. Can detect individual particles, perhaps as small as 30 microns diameter.

3. Has been used for micrometeorite detection.

B. Disadvantages

1. Can sense only particles larger than about 30 microns diameter.
2. Probably cannot detect concentrations as high as those in smoke stacks.
3. Small particles would interfere with the detection of large ones by contaminating the impact surface.
4. Has not been used for purposes other than micrometeorite detection on spacecraft.
5. The gravimetric microbalance technique would have severe interference by the air jet from the impactor.
6. Contamination of the sensor would probably cause measurement errors; periodic cleaning is required.
7. Different responses will probably result depending on whether or not the particle sticks to the sensor.
8. Requires sampling probe and is subject to probe loss errors.
9. Probably requires conditioning of the sample stream.

C. Recommendations for Further Development

We recommend no further development of this technique for particulate mass monitoring in smoke stacks at this time. However, clever design combinations could appear in the future calling for reevaluation of the technique, especially if particle sizing could be done by the same instrument and if the technique becomes useful for particles as small as 1 micron.

D. Conclusions

A variation of this technique is capable of detecting the mass of individual particles larger than 30 microns diameter. However, it is not sensitive enough to detect smaller particles with the present known technology. Other variations have similar problems as listed above. The technique may be useful for some particle sizing applications of large particles, but does not look promising for mass concentration monitoring at this time.

CAPACITANCE-IMPACT SENSING

PRINCIPLE OF OPERATION

If a particle hits one plate of a capacitor with enough momentum, the plate moves slightly causing a change in the capacitance of the system. In its simplest form, this principle can monitor the momentum of moving particles. If airborne particles are first accelerated to a constant velocity in a nozzle, the magnitude of the measured change in capacitance becomes independent of particle velocity and dependent only on particle mass.

An instrument of this type for particulate mass concentration monitoring consists of a nozzle which accelerates the particles to near sonic velocity, an aerodynamically stablized, very thin, capacitor lamella, and a RMS voltmeter, as an indicator. Such an instrument has been used to monitor mass concentrations above 15 mg/m^3 of particles in the 1 - 20 micron size range. The lower size limit is set by the impaction efficiency of the system (probably 0.3 - 1.0 μm). The upper size limit is probably above 100 μm.

COMMERCIAL EQUIPMENT

No commercial equipment of this type exists. Only three research prototypes have been reported.

REFERENCES

Reference 1248 discusses this technique.

DISCUSSION

A. Advantages

1. May sense a parameter closely related to the mass of particles.
2. In a second mode of operation, the same instrument can obtain some particle size information.
3. High sensitivity, can sense concentrations at least down to 10 mg/m^3.
4. Can probably operate at temperatures as high as 1000°F.
5. Essentially instantaneous and continuous readout.
6. Appears to be simple and inexpensive, potential cost of commercial instrument is in the \$2,000 - \$5,000 range.
7. Compact sensing head.

B. Disadvantages

1. Almost no development has been done for any applications, only three prototypes have been reported.
2. Correlation with mass is not presently established.
3. Requires lamella cleaning or replacement periodically with some related system complexity.
4. Requires the lamella to be aerodynamically stable with no flutter.
5. Requires sampling probe and is subject to probe loss errors.
6. Requires particle deposition.
7. May require some conditioning of the sample stream.

C. Recommendations for Further Development

We recommend that the only reported research on this technique, performed in France, be investigated in detail. If the technique looks promising after more details of the French work are known, feasibility studies for stack monitoring should have high priority. Cleaning or replacing the lamella for automatic operation may be a major problem. Problems with maintaining aerodynamic stability of the lamella limit the lowest concentration which the sensor can detect. The ability of the technique to sense mass must be tested.

D. Conclusions

This technique is potentially one of the best methods of monitoring particulate mass concentration in smoke stacks, primarily because it may sense a parameter closely related to the mass of particles, the technique and apparatus is very simple and inexpensive, and it can give instantaneous and continuous readout. It is not clear how closely the measurement correlates with mass. Potential problems appear to be periodic cleaning or replacing of the lamella for automatic operation and maintaining aerodynamic stability of the lamella. The technique is very new with only three prototype instruments constructed. Development is needed to make the technique into a reliable instrument for stack monitoring. The reported prototype instruments (see Ref. 1248) should be investigated further, and feasibility tests for stack monitoring should proceed if the investigation indicates high potential. The apparent low cost and simplicity recommend it highly for such studies.

ELECTROSTATIC CONTACT CHARGE TRANSFER: KONITEST

PRINCIPLE OF OPERATION

As particles slide along a wall, they exchange electrostatic charge with the wall. In the Konitest, particles whirl through a tube in a helical path. Centrifugal force causes many particles, especially the larger, heavier ones, to hit and slide along the wall, exchanging electrostatic charge with the wall. An electrometer measures the current flowing from the electrically-floating wall. The current level can be calibrated to read particle concentration. A second design, with the same name, uses an electrically-floating venturi as the surface which exchanges charge with particles. The second design differs little from the probe-in-nozzle technique discussed separately in this report.

The first Konitest design differs from other electrostatic techniques in that centrifugal force causes particles to strike the cyclone wall and slide or bounce along the surface. Thus, larger particles containing most of the mass have a greater effect than smaller ones. If there is no secondary interference by submicron particles, the calibrated output current can correlate reasonably well with particulate mass in certain effluent streams. Little is known about the actual charge transfer process.

COMMERCIAL EQUIPMENT

Until recently, the Konitest was manufactured by J. C. Eckardt A. G., 7000 Stuttgart-Bad Cannstatt, Postfach 347, West Germany. However, this company no longer makes the instrument. No other manufacturer is known.

REFERENCES (See ELECTROSTATIC MEASUREMENT METHODS in Volume II)

A. Principle of Operation: 923, 241

B. Applications: 1189, 659, 923, 225

C. Data: 1189, 923, 241, 1188

D. Specific Instrument Descriptions: 923, 241

DISCUSSION

A. Advantages

1. Continuous, nearly instantaneous readout.
2. Can operate at stack temperatures, eliminating several sample conditioning problems.
3. Senses larger particles which contain most mass.
4. Self-cleaning if some particles are large, somewhat abrasive, and not sticky.

5. Operates over a wide concentration range.

6. Has been marketed commercially in the past.

7. Available data appears to show surprisingly good correlation with particulate mass concentration.

8. Sensor is compact and easy to operate.

B. Disadvantages

1. Several investigators mention high sensitivity to submicron particles leading to highly erroneous mass concentration measurements.

2. Response depends strongly on particle size and composition, on surface characteristics of the particle and probe, and may depend on the initial charge on the particle.

3. Principle of operation is largely unknown.

4. Does not sense particle mass, but may sense something close to it for some aerosols; periodic calibration of each instrument installation appears necessary.

5. Requires some large, non-sticky, abrasive particles to keep the tube clean.

6. Requires measurement of low currents in effluent atmospheres.

7. Requires sampling probe and is subject to probe loss errors.

C. Recommendations for Further Development

We recommend an intensive investigation of past experience with the Konitest, primarily in Germany where it has been sold for about 10 years. Several investigators indicate excellent correlation with particulate mass concentration in coal-fired effluent streams. Others report overwhelming sensitivity to submicron particles which do not have much mass. These reports appear to conflict, as do the reports on operational problems with the Konitest. If the recommended investigation uncovers better documented evidence supporting the reported excellent mass correlation, we recommend further testing and development of this technique.

D. Conclusions

The Konitest is reported to have excellent correlation with particulate mass concentration with coal-fired effluents. If this is true, the instrument could be an excellent, truly continuous, fast response, compact, reliable, automatic stack monitor. However, conflicting reports claim very poor mass correlation because of high sensitivity to submicron particles. The theory is not well developed and, therefore, does not resolve the problem. Only further discussions with past users, perhaps followed by a testing and development program, can resolve the conflicting reports. In any case, since the Konitest does not measure particulate mass directly, periodic calibration of every installation would be required of any instrument using this principle. This may be a severe limitation. Another probable negative feature of the instrment is that, although mass correlation may be excellent during the large majority of the time when the process is under control, mass correlation may be very poor during the times when something happens to the process causing severe changes in emissions. This is precisely the time when accurate mass measurements are most valuable.

ELECTROSTATIC CONTACT CHARGE TRANSFER: BOUNCE

PRINCIPLE OF OPERATION

Particles will bounce between the plates of a high voltage electric capacitor as they are carried through by an airstream. As particles enter the capacitor, they are attracted electrically to one capacitor plate or the other, because of any initial electrostatic charge or because of charge picked up in the capacitor's electric field. Upon hitting the first plate, the particle loses its old charge and gains a new charge with the same polarity as the first plate. The repulsion of the particle by the first plate, caused by their like polarity, forces the particle to migrate toward the second plate, carrying electrical charge with it. When it hits the second plate, it again loses its old charge and picks up a new charge with the same polarity as the second plate. The new charge causes the particle to migrate toward the first plate, carrying electrical charge with it, where the entire process is repeated. The net current flow across the capacitor plates is a measure of the concentration of particles passing through. The technique reportedly works well for dry, non-sticky particles, especially above 100 μm, but sometimes as small as 1 μm.

COMMERCIAL EQUIPMENT

No commercial equipment exists and little laboratory equipment exists.

REFERENCES (See ELECTROSTATIC MEASUREMENT METHODS in Volume II)

Reference 226 discusses all aspects of this technique including a description of a prototype instrument.

DISCUSSION

A. Advantages

1. Continuous, nearly instantaneous readout.
2. Senses large particles which contain most mass.

B. Disadvantages

1. Does not sense particle mass or a parameter very close to mass.
2. Works only with large, dry, non-sticky particles; almost certainly would not work in coal- or oil-fired effluent stacks.
3. Not well developed; only one investigator is known.
4. Probably contamination sensitive.

5. Requires measurement of low current levels in effluent atmospheres.

6. Requires sampling probe and is subject to probe loss errors.

7. Probably requires conditioning of the sample stream.

C. Recommendations for Further Development

We recommend no development of this technique for stack effluent monitoring.

D. Conclusions

This technique cannot be used to monitor stack effluents because of the reason listed as disadvantage 2 above.

ELECTROSTATIC CONTACT CHARGE TRANSFER: PROBE-IN-NOZZLE

PRINCIPLE OF OPERATION

When particles bounce off a surface, they usually exchange some electrostatic charge with the surface. The quantity and polarity of the exchanged charge depends on the composition of the particles and surface, on the surface characteristics of both, on the intensity of the collison, and on the initial charge carried by both. The process is not understood well enough to analyze mathematically.

An instrument using this principle has been designed. A cone-shaped probe points upstream within the throat of a venturi nozzle. Most large particles passing through the nozzle strike theprobe and bounce off, resulting in a charge transfer. An electrometer attached to the probe indicates the magnitude of the charge transfer, which can be related to aerosol concentration by suitable calibration.

COMMERCIAL EQUIPMENT

No commercial equipment exists which uses this principle for measuring particle concentration. Only laboratory equipment exists.

REFERENCES (See ELECTROSTATIC MEASUREMENT METHODS in Volume II)

A. Principle of Operation: 187, 104, 5, 659

B. Applications: 20, 1036, 684, 659

C. Data: 20, 104, 1036, 684, 922, 5, 659

D. Specific Instrument Descriptions: 20, 104, 1036, 684, 922, 5, 659

DISCUSSION

A. Advantages

1. Continuous, nearly instantaneous readout.
2. Senses large particles which contain most mass.
3. Self-cleaning if some particles are large, somewhat abrasive, and not sticky.
4. Operates over a wide concentration range.

B. Disadvantages

1. Does not sense particle mass or a parameter closely related to mass.
2. Response depends strongly on particle size and composition, on surface characteristics of the particle and probe, and on the initial charge on the particle.
3. Requires some large, non-sticky, abrasive particles to keep the probe clean.
4. Requires measurement of low currents in effluent atmospheres.
5. Requires sampling probe and is subject to probe loss errors.
6. May require some conditioning of the sample stream.

C. Recommendations for Further Development

We recommend no development of this technique for coal- or oil-fired effluent monitoring.

D. Conclusions

This technique is not suitable for use in monitoring stack effluents because of reasons listed as disadvantages 2 and 3 above.

ELECTROSTATIC ION CAPTURE AND ION CURRENT ATTENUATION

PRINCIPLE OF OPERATION

If a constant supply of unipolar ions flows perpendicularly across a stream of airborne particles toward the grid of an electrometer, some of the ions will strike the particles, become captured, and be carried away, thus reducing the ion current as measured by the electrometer. The reduction in ion current, known as ion current attenuation, is a measure of the particle flow rate.

The ion capture technique measures the other portion of the total ion current: the portion carried away by particles. The particles must be collected downstream of the charging region by some means such as filtration or electrostatic precipitation, the charge from the particles must leak through an electrometer.

COMMERCIAL EQUIPMENT

No commercial equipment exists for monitoring stack effluents. One company manufactures a sophisticated version of ion capture as a submicron particle sizing instrument:

Thermo-Systems Inc.
2500 North Cleveland Avenue
St. Paul, Minnesota 55113

Several laboratory prototypes of stack monitors exist.

REFERENCES (See ELECTROSTATIC MEASUREMENT METHODS in Volume II)

A. Principle of Operation: 68, 1211, 8, 916, 554, 122, 245, 1040, 284, 242

B. Applications: 659, 552, 916, 554

C. Data: 659, 1040, 302, 8, 554, 122, 245, 1040, 284, 242

D. Specific Instrument Descriptions: 659, 242, 581, 68, 302, 916, 554, 122, 284

DISCUSSION

A. Advantages

1. Continuous, nearly instantaneous readout.
2. Can operate at stack temperatures, eliminating several sample conditioning problems.

3. Several investigators have operated instruments in coal-fired effluents with some success.

4. Sensor is compact and easy to operate.

5. Simple technique available for drawing particles through the sensor eliminating many isokinetic sampling problems and much equipment.

6. Unique suction technique makes readout proportional to particle flow rate rather than particle concentration, making auxiliary measurements of gas velocity unnecessary.

B. Disadvantages

1. Does not sense particle mass or a parameter closely related to mass.

2. Response depends strongly on particle size with very high sensitivity to submicron particles which do not contain much mass.

3. Requires periodic cleaning by an auxiliary technique.

4. Requires measurement of low currents in effluent atmospheres.

5. Requires sampling probe and is subject to probe loss errors.

C. Recommendations for Further Development

We recommend no further development of this technique for particulate mass measurements. However, further development as a monitor for other particle concentrations or flow rates, such as total surface area flow rates, is strongly recommended.

D. Conclusions

This technique cannot measure particulate mass flow rate or concentration. However, the technique is a strong candidate for other particle concentration measurements, for example, measurements based on total surface area of the particulate cloud. The point sampling feature, the compactness, and the instantaneous, continuous readout should recommend this technique for some research applications as well as for evaluating specific portions of an electrostatic precipitator.

CAPACITANCE-DIELECTRIC CHANGE

PRINCIPLE OF OPERATION

If the dielectric strength of the material between the plates of a capacitor changes, the capacitance of the system changes. If the composition of the material remains constant, the change in dielectic strength depends primarily on the mass of material between the plates. This technique has been used to detect the presence of the powder particles in both pneumatic and belt conveying systems. The resolution of these instantaneous readout devices is apparently not high enough to accurately measure flow rates, even in systems with high particle concentrations. However, it may be possible to collect enough particles on a suitable substrate, such as a filter or impaction plate, so that the mass of material could be periodically measured in a batch process. The instrument would consist of a particle collector, a capacitance sensor with an appropriate electrical circuit, and a system to move the substrate for each batch from the collector to the sensor.

COMMERCIAL EQUIPMENT

No commercial equipment exists. Several powder detection prototypes have been tested.

REFERENCES

This technique was suggested for aerosol measurements by B. Y. H. Liu in private conversations. References 4 and 1031 discuss the powder detecting systems.

DISCUSSION

A. Advantages

1. Detects a parameter related to the mass of particles for a given particulate composition.

2. Can be used with several particle collectors.

3. May need little calibration within each stack _if_ the dielectric constant of the material remains constant.

4. Should be relatively simple to operate.

B. Disadvantages

1. Almost no development of the technique has been done, feasibility not yet proven.

2. May lack sufficient sensitivity.

3. Dielectric constant of stack effluents may not remain constant, probably requires an initial calibration for each installation at each operating condition.

4. Readout not instantaneous or continuous.

5. Requires sampling probe and is subject to probe loss errors.

6. Requires particle deposition.

7. May require conditioning of the sampling stream.

8. Requires replacement or cleaning of the collection substrate for every measurement.

C. Recommendations for Further Development

We recommend that preliminary feasibility tests of this technique be made soon. Further development should depend on the results of such tests. A serious problem may be a lack of sufficient sensitivity.

D. Conclusions

This technique has more promise than most techniques, primarily because it measures a parameter somewhat related to particulate mass if the dielectric constant of particulate matter remains constant. However, the possible lack of sensitivity may severely restrict the use of this principle. The feasibility of the technique has not yet been tested. This technique requires several years of development to reach the commercial instrument stage, and offers somewhat less promise than techniques listed earlier.

LIGHT TRANSMISSION

PRINCIPLE OF OPERATION

When light, or other electromagnetic radiation, passes through an aerosol, its intensity decreases because of scattering and absorption by the particles. The transmission or attenuation of light through an aerosol is a measure of the aerosol concentration. In order to measure the particle mass concentration, particle size, shape, optical characteristics and density must remain constant. The relationship between particle mass concentration and light transmission must be established by calibration of each instrument within every stack under every plant operating condition.

Despite the severe limitation in terms of mass concentration measurement, light transmission is now the most widely used principle for continuous monitoring of smoke emissions from stacks. The technique has several impressive practical advantages, and the measurements correlate quite well with the visual appearance of the effluent. Although light transmission may remain an important effluent monitoring technique, measurements made in this way must not be confused with the mass concentration of particles in the effluent. In practical situations, particle mass concentration must be measured by other techniques.

COMMERCIAL EQUIPMENT

A number of companies manufacture and/or sell light transmission instruments for installation in smoke stacks including:

Airflow Developments (Canada) Ltd.
244 Newkirk Road
Richmond Hill, Ontario, Canada

Bailey Meter Company
29801 Euclid Avenue
Wickliffe, Ohio 44092

Cleveland Controls, Inc.
1111 Brookpark Road
Cleveland, Ohio 44109

Combustion Equipment Associates, Inc.
120 Park Avenue
New York, New York 10017

Durag Apparatebau Gmbh
2 Hamburg 61
Killanstrasse 105,
West Germany

Electronics Corporation of America
Photoswitch Division
3 Memorial Drive
Cambridge, Massachusetts 02142

General Electric Company
Communication and Control Devices Department
Waynesboro, Virginia 22980

Infra-Red Industrial Systems Division
Ovitron Corporation
1425 Milldale Road
Cheshire, Connecticut 06410

Intertech Corporation
262 Alexander Street
Princeton, New Jersey 08540
(U.S. representative for Irwin Sick
Optik Elektronik
Neuried, West Germany)

Leeds & Northrup Company
4901 Stenton Avenue
Philadelphia, Pennsylvania 19144

Mac Leod & Stewart Company, Inc.
43 Rome Street
Farmingdale, Long Island, New York 11735

Nebetco Engineering
1107 Chandler Avenue
Roselle, New Jersey 07203

Photobell Company, Inc.
12 East 22nd Street
New York, New York 10010

Photomation, Inc.
280 Polaris Avenue
Mountain View, California 94040

Reliance Instrument Manufacturing Corporation
141 Lawerance Avenue
Hackensack, New Jersey 07601

Sentry Controls, Inc.
P.O. Box 116
Pearl River, New York 10965

Robert H. Wager Company, Inc.
Passaic Avenue
Chatham, New Jersey 07928

REFERENCES (See LIGHT TRANSMISSION and MULTI-WAVELENGTH LIGHT TRANSMISSION in Volume II)

A. Principle of Operation: 1211, 485, 147, 1201, 1214, 1215, 843, 1212, 1199, 1250, 33, 1213, 34

B. Applications: 487, 13, 718, 964, 485, 34, 637, 1189, 225, 1230

C. Data: 485, 1201, 1211, 1215, 846, 847, 848, 1181, 1200, 33, 1213, 718, 964, 34, 1189, 225, 1230

D. Specific Instrument Descriptions: 950, 963, 850, 851, 193, 1033, 487, 13, 485, 34, 637, 225, 1230

DISCUSSION

A. Advantages

1. Measures the optical density of suspended particles in a portion of the stack without removing them or depositing them.
2. High reliability easily possible because of relative mechanical simplicity.
3. Lower initial cost than most other techniques if necessary calibration is ignored.
4. Several commercial instruments exist.
5. No moving parts are necessary.
6. Instantaneous, continuous measurement readout which is easy to record.
7. Measures average concentration over a long path, an advantage in some applications if carefully used.

B. Disadvantages

1. Does not detect particle mass, but some other parameter which is poorly related to mass concentration.
2. Requires extensive repeated calibrations of each installation under each plant operating condition for correlation with particle mass concentration. Small changes in plant operating conditions can result in measurement uncertainties of typically $^{+200}_{-100}$ % without such calibration.
3. Yields erroneous measurements during normal plant operations such as rapping and soot-blowing.

4. Becomes very expensive with the necessary calibrations.
5. Even with careful calibration, plant operating conditions must be known at all times in order to interpret the data.
6. Does not fit most existing sampling access ports, requiring higher cost of installation.
7. Requires careful placement, installation, and alignment.
8. Present manufacturers have a somewhat established market in the United States, making the introduction of new, more accurate mass concentration monitors more difficult.
9. Present commercial instruments often show poor correlation with each other.

C. Recommendations for Further Development

Although we reject this technique for particle mass concentration measurements, we recommend extensive development and testing of light-transmission instruments for use as optical density monitors. Different models of present commercial instruments show poor correlation with each other, suggesting the need for standardization of instrument design. Before that, however, extensive development and testing is needed to identify the "best" design. We recommend that a carefully-planned, long range program be undertaken which will result in an instrument design worthy of standardization. Such a program must also increase the knowledge of what light transmission instruments in stacks really measure.

D. Conclusions

Measurements made with this technique correlate very poorly with the mass concentration of aerosol particles. Thus, for most stack monitoring applications, the light transmission technique must be rejected for measurements of particle mass concentration. However, the technique will undoubtedly be used for monitoring optical density in stacks for some time to come because the measurement does correlate somewhat with the visual appearance of the plume and because instruments using the technique have several important practical advantages. A number of companies manufacture light transmission instruments. Considerable development of both theory and hardware is necessary to evaluate what is being measured. The lack of good correlation between the many light transmission instruments is disturbing. Although careful design could improve the correlation of light transmission measurements with particle mass concentration, this technique is not capable of accurate mass measurements.

LIDAR

PRINCIPLE OF OPERATION

Lidar, the optical analog of radar, uses the backward reflection of light from particles as a way of measuring particle concentration. The lidar light source is a laser and the detector is a photomultiplier. The source and detector are generally located close to each other. Most instruments have been made to study aerosol clouds 100m to 100 km from the lidar unit.

A typical lidar system consists of a laser, sending telescope, receiving telescope, and signal detector. Light pulses of very short duration (30×10^{-9} sec) and high energy (45 megawatts) are directed through the sensing telescope toward the cloud. Energy returned by the atmosphere is collected by a similar telescope and sensed by a photomultiplier. As with most optical particle sensing methods, the size and optical properties ofthe particle must be known for accurate data interpretation. Lidar has proven itself useful in defining the boundaries of aerosols plumes and clouds at some distance from the observer.

COMMERCIAL EQUIPMENT

Only research prototype lidar units exist.

REFERENCES (See LIDAR in Volume II)

A. Principle of Operation: 66, 221, 149

B. Applications: 280, 221, 569, 514, 149, 89, 66

C. Data: 280, 221, 569, 514, 89, 149

D. Specific Instrument Descriptions: 286, 802, 221, 89

DISCUSSION

A. Advantages

1. Measures some concentration of particles remotely from the observer.
2. Requires no sampling or particle deposition.
3. Senses a wide range of concentrations.
4. One instrument, located at some central location outside the stack, can monitor a number of stacks in turn.
5. Can measure the particles just after entering the atmosphere from the stack.

6. Source and detector can be located in one housing, measurement is single-ended and truly remote.
7. Lidars have been used to monitor stack plumes.
8. Remote monitoring removes the problems of high temperature and the otherwise harsh stack environment.
9. Can scan a cloud to obtain concentration profiles and cloud boundaries.
10. Cost can be low for monitoring a number of stacks remotely with one unit.

B. Disadvantages

1. Does not measure the mass of particles.
2. Particle size, density, and optical properties must be known to interpret the data accurately.
3. The measured parameter is not readily defined.
4. Technique not fully understood and developed yet.
5. Only sophisticated research equipment exists.
6. Present units are too expensive for monitoring single stacks.

C. Recommendations for Further Development

We do not recommend development of lidar as a particle mass concentration detector because the technique cannot sense mass. Even though it is not within the scope of this report, we recommend this technique highly as a remote monitor of particulate emissions from a number of stacks with one centrally-located instrument. Further studies should include better definition of the measured particulate parameter.

D. Conclusions

Lidar cannot measure the mass concentration of particles in or from a smoke stack. However, lidar appears to have excellent potential for remotely monitoring a number of stacks with one, permanently - installed instrument. This application would seem to be very useful in identifying possible emissions violators. After such identification, more careful particle mass concentration measurements could be made for more definite proof of violations. Thus, although lidar cannot fill the needs of a particle mass emissions monitor, it appears to be a potentially useful tool for pollution abatement.

HOLOGRAPHY

PRINCIPLE OF OPERATION

Holography is an interferometric technique by which three-dimensional information can be recorded on a two-dimensional photograph. The process consists of photographing the interference pattern that exists when a diffracted or object field (Fresnel or Fraunhofer diffraction pattern of the object) is allowed to interfere with a reference or background wave. The image can be reconstructed in three-dimensions by illuminating the film record with a coherent beam of quasi-monochromatic light.

Holography can be used to find the size and number distribution of an aerosol which passes through a given volume. The reconstructed holograms can be displayed on a TV monitor. Manual or automatic scanning techniques can then obtain the number concentration as a function of particle size in the 1 to 500 μm range. This information could be transformed into the total volume occupied by particles in a given volume of gas.

COMMERCIAL EQUIPMENT

Several companies manufacture and/or market holographic equipment for research purposes. Three companies that market equipment which can be specifically applied to particle holography are:

Stat Volt Company
1130 Channel Drive
Santa Barbara, California 93103

Optics Technology Inc.
901 California Avenue
Palo Alto, California 94304

Technical Operations Inc.
South Avenue
Burlington, Massachusetts 01803

REFERENCES (See HOLOGRAPHY in Volume II)

A. Principle of Operation: 150, 1195, 1197, 128, 682, 253, 126, 132, 784

B. Applications: 1197, 682, 253, 150, 483, 1198, 3, 516, 633

C. Data: 1198, 150, 3

D. Specific Instrument Descriptions: 148, 253, 483, 150, 1196, 3

DISCUSSION

A. Advantages

1. Does not require particle deposition or disturbing the aerosol flow stream.

2. Records permanent, 3-dimensional photographs of particles.

3. Can be used to measure particle size and number concentration plus some particle shape information.

B. Disadvantages

1. Very expensive at the present time and for some time to come.

2. Does not measure true particle mass, although it can measure particle volume.

3. Does not lend itself easily to automation without added expense and complex equipment.

4. Principle of operation is quite complicated.

C. Recommendations for Further Development

We do not recommend development of holography for particle mass concentration measurement at this time. The technique will undoubtedly be useful for studying the size, shape, and number concentration of particles in their natural state. Therefore, development for purposes other than particle mass measurement may be justified.

D. Conclusions

Holography is not a feasible monitor of particulate mass emissions from stacks at this time and probably will not be in the future. The system appears to be much too expensive and complex for such purposes. Undoubtedly, many other uses will be found for holography, including research study of particle size, shape, and concentration in the natural suspended state within smoke stacks.

OPTICAL COUNTERS AND PHOTOMETERS

PRINCIPLE OF OPERATION

An optical counter measures and counts individual particles by light scattering or extinction. Particles in an aerosol cloud are led single-file through a light beam where they scatter and absorb a certain amount of light depending on the particle size, the optical characteristics of the particle, and the light beam characteristics. Most optical counters detect the light scattered in a given direction by means of a photomultiplier. The output data is generally given as the number of particles within a given particle size range per unit gas volume. Modified commercial optical counters are limited to particle diameters of 0.2 μm to about 70 μm. Aerosol concentrations entering well-designed optical counters must be less than about 10^7 particles per cubic foot within the sensing range of the instrument. Some optical counters detect the amount of light blocked out by the particle. Optical counters are also known as single particle optical counters, aerosol counters, particle counters, and dust counters.

Photometers, often called nephelometers, perform their measurement on a cloud of aerosol particles by light scattering. They are useful for measuring aerosol concentration. In a photometer, a light beam shines through the cloud of aerosol particles. A photomultiplier measures the intensity of light scattered at a certain angle by the particles. The intensity of the scattered light depends on the particle size and concentration, on the optical characteristics of the light beam. Correlation with particle mass concentration requires that all these parameters except concentration remain constant. Photometers can measure aerosol clouds with considerably higher concentrations than can the optical counter.

COMMERCIAL EQUIPMENT

A number of companies manufacture optical counters, primarily for use as clean room monitors, but with several models for use as ambient atmospheric aerosol monitoring:

Royco Instruments, Inc.
141 Jefferson Drive
Menlo Park, California 94025

Bausch & Lomb
635 St. Paul Street
Rochester, New York 14602

Climet Instruments, Inc.
1240 Birchwood Drive
Sunnyvale, California 94086

High Accuracy Products Corporation
141 Spring Street
Claremont, California 91711

Coulter Electronics Industrial Division
590 West 20th Street
Hialeah, Florida 33010

Dynac Corporation
Thomson's Point
Portland, Maine 04120

Phoenix Precision Instrument Company
3803-05 North Fifth Street
Philadelphia, Pennsylvania 19140

Envirco
P. O. Box 6098
Albuquerque, New Mexico 87107

Several companies manufacture aerosol photometers for atmospheric aerososl:

Phoenix Precision Instrument Company
3803-05 North Fifth Street
Philadelphia, Pennsylvania 19140

Meteorology Research, Inc.
Box 637
464 West Woodbury Road
Altadena, California 91001

Royco Instruments, Inc.
141 Jefferson Drive
Menlo Park, California 94025

Envirco
P. O. Box 6098
Albuquerque, New Mexico 87107

REFERENCES (See OPTICAL COUNTERS and PHOTOMETERS in Volume II)

A. Principle of Operation: 143, 515, 362, 813, 625, 840, 1083, 1192, 1082, 578, 132, 680, 1211

B. Applications: 711, 732, 731, 840, 124, 919, 69, 928, 285, 225, 288, 1110, 993, 307, 578, 580, 559, 1180

C. Data: 993, 988, 731, 171, 680, 132, 928, 69, 919, 1083, 374, 285, 752, 340

D. Specific Instrument Descriptions: 145, 146, 370, 580, 1210, 756, 670, 615, 120, 1128, 949, 824, 276, 598, 1066, 822, 876, 1082, 362, 346, 840, 124, 928, 288, 1192, 1193, 1194, 969, 287

DISCUSSION

A. Advantages

1. Optical counters can detect very low concentrations (a single particle within the sensitive size range passing through the instrument) and upper concentrations of about 10^7 particles per cubic foot within the specified size range.
2. Optical counters can measure particle size distribution in the 0.2 - 70 μm diameter range if correctly designed.
3. Readout of photometer is instantaneous, continuous, and easy to record.
4. Automatic instruments are commercially available for ambinet air and clean room monitoring.

B. Disadvantages

1. Neither optical counters nor photometers measures particle mass, correlation with mass is not good.
2. Both types of instruments, especially the optical counter, are designed for clean room and other low concentration aerosols.
3. Both instruments require sampling probe and are subject to probe loss errors.
4. Both instruments require conditioning of the sample stream, including considerable dilution to measure stack concentrations.
5. Calibration of the instruments changes with changes in particle optical properties.
6. Both instruments lack the wide size range necessary for mass measurements.
7. Changes in the specific gravity of particles causes errors in estimating particulate mass.

8. Two particles passing through an optical counter at one time are counted as one particle.
9. Fluctuations in the number concentration of particles smaller than the lower size limit of optical counters cause errors in counting of particles in the lower size ranges.

C. Recommendations for Further Development

We recommend no development of these techniques as particle mass concentration monitors. A good dilution and sample conditioning system is necessary for use of either device in specific research applications.

D. Conclusions

These techniques cannot measure the mass concentration of airborne particles. Correlation of these measurements with particle mass concentration is very poor. These instruments share most of the problems of light transmission instruments and also have several additional problems for particle mass concentration monitoring. Optical counters may be useful for particle size distribution measurements of stack effluents after development of a sample conditioning system. Photometers may find specialized research application for measurement of stack effluents.

ANGULAR LIGHT SCATTERING

PRINCIPLE OF OPERATION

Light scattering is the redirection of illumination which is incident upon the object. Scattered light is a combination of transmitted, reflected, and diffracted light, and depends upon characteristics of the object, the surrounding medium, and the incident radiation. Important parameters which influence light scattering are light wavelength, particle size and shape, refractive index of the particle with respect to the medium, and the angle at which an observer is located in relation to the incident light. Light scattered at various angles from the direction of illumination provides a means of studying aerosols. The light intensity as a function of observation angle provides information which describes particle size if the index of refraction and light wavelength are known and the particle is spherical.

COMMERCIAL EQUIPMENT

No commercial equipment is known which uses this principle for aerosol measurements. Only laboratory prototypes exist.

REFERENCES (See ANGULAR LIGHT SCATTERING in Volume II)

A. Principle of Operation: 147, 1201, 1211, 702, 1203, 909, 1233, 70, 842, 38, 474, 805, 85, 1235, 1236, 1237, 1238

B. Applications: 702, 909, 1234, 1237, 1238

C. Data: 474, 805, 85, 1203, 1234, 1232

D. Specific Instrument Descriptions: 842, 1211, 38, 787

DISCUSSION

A. Advantages

1. Can measure particle concentration without depositing the particles onto a surface.

2. Can measure particle concentration more accurately than standard light transmission or scattering because particle size is partially measured.

3. Can detect low concentrations.

4. Potentially, rapid measurements are possible.

B. Disadvantages

1. Cannot measure particle mass or a parameter closely related to mass.
2. Procedure is presently manual and does not lend itself to automatic stack monitoring.
3. Data reduction is complicated and requires expensive equipment.
4. Results with adequate accuracy for stack monitoring are probably not possible.
5. Only research equipment has been constructed.
6. Considerably more theory and development remain to be done if practical instruments are to result.

C. Recommendations for Further Development

We recommend no further development as a particulate mass monitor. Further research and development may be justified for other types of particle measurements in stacks.

D. Conclusions

Angular light scattering cannot measure particulate mass concentration. Some research applications for the technique in stack effluents may be found.

SOILING POTENTIAL

PRINCIPLE OF OPERATION

As a filter becomes loaded with particles, the amount of light which can be transmitted through the filter decreases. The unit of measurement, called the coefficient of haze (Coh), corresponds with the optical density of the filter deposit. Another system with reflectance units of dirt (Rud), measures the stain potential due to light reflection rather than transmission. Soiling potential instruments usually consist of an indexing tape filter with a light source on one side of the filter deposit and a light detector on the other side.

COMMERCIAL EQUIPMENT

Several companies manufacture and/or sell soiling potential instruments for ambient air sampling including:

Research Appliance Company
Route 8 & Craighead Road
Allison Park, Pennsylvania 15101

Gelman Instrument Company
P. O. Box 1448
600 South Wagner Road
Ann Arbor, Michigan 48106

Precision Scientific
3737 West Cortland Street
Chicago, Illinois 60647

Leigh Systems,Inc.
220 Boss Road
Syracuse, New York 13211

Von Brand
Rhinebeck, New York 12572

Some of the ambient air monitors may adapt to stack monitoring with little modification.

REFERENCES (See SOILING POTENTIAL in Volume II)

A. Principle of Operation: 519, 396, 831, 305

B. Applications: 519, 396, 831, 305

C. Data: 519, 396, 831, 305

D. Specific Instrument Descriptions: 519, 396, 831, 305

DISCUSSION

A. Advantages

1. Several commercial models available for ambient air sampling; modification for stacks appears simple.

B. Disadvantages

1. Does not measure the mass of particles.
2. Particle size, density, and optical properties affect the measurement severely.
3. Requires sampling probe and is subject to probe loss errors.
4. Probably requires conditioning of the sample stream.
5. Requires particle deposition.
6. Requires an automatic advancing mechanism for the filter.
7. Difficult to make readout continuous and instantaneous.
8. Filter tape in present models needs replacement every 1 - 4 weeks.

C. Recommendations for Further Development

We recommend no development of this technique as a particle mass concentration monitor.

D. Conclusions

This technique cannot measure the mass concentration of airborne particles. The soiling index may be a useful measurement for pollution monitoring programs, but measurements cannot be expected to correlate with particle mass concentration. The technique shares nearly all the problems of light transmission measurements while having the additional problems of extraction sampling.

ACOUSTICAL ATTENUATION AND DISPERSION

PRINCIPLE OF OPERATION

Acoustical attenuation is the decrease in amplitude of an acoustical pressure wave traveling through a media due to such effects as interactions with walls and suspended particles. Two mechanisms account for practically all the attenuation caused by particles. One is viscous energy loss caused by the lagging motion of the particles as the acoustic wave passes. The other mechanism is thermal energy loss caused by the irreversible flow of heat between the suspended particle and the gas during rarefactions and compressions of the sound wave.

Acoustical dispersion is the decrease in sound velocity due to the presence of particulate matter in the gas. Particles added to a gas cause an increase in heat capacity and an increase in the density of the gas-particle mixture. Both result in a lower sound velocity.

COMMERCIAL EQUIPMENT

No commercial equipment using this principle is available for measuring particles. Only laboratory equipment exists.

REFERENCES (See ACOUSTICAL ATTENUATION AND DISPERSION in Volume II)

A. Principle of Operation: 138, 139, 604, 616

B. Applications: 314, 600

C. Data: 103, 138, 139, 605

D. Specific Instrument Descriptions: 314, 557

DISCUSSION

A. Advantages

1. Measures suspended particles without first depositing them.
2. Probably insensitive to contamination of apparatus.

B. Disadvantages

1. Does not sense particle mass concentration.
2. Sensitive only to very high concentrations, not sensitive to stack concentrations.
3. Response is dependent on particle size.

4. Instruments require batch sampling with relatively long stabilizing time.

5. Principle not well understood.

6. No feasible instrument design yet discovered.

C. Recommendations for Further Development

We do not recommend further development at this time. More basic research for developing a better understanding of the principle is needed. New methods for utilizing the principle may result from such programs. However, a number of other particle measurement techniques appear considerably more promising.

D. Conclusions

Acoustic attenuation and dispersion are not practical methods for measuring particle concentration in smoke stacks. Particle-acoustic interactions are in the research stage and little practical use has been found for the technology to date. We see little chance that practical instruments using this technology can be developed in the next 5 - 10 years.

ACOUSTICAL PARTICLE COUNTER

PRINCIPLE OF OPERATION

Particles cause an audible "click" when passing through or leaving a laminar capillary. The intensity of the "click" is somewhat related to particle size, but the exact relationship is not yet known. Although the phenomena is not very well understood, it can be used to count individual particles. Particles below 5 μm cannot be detected. The resulting measurement is the number concentration of particles above 5 μm.

COMMERCIAL EQUIPMENT

No commercial equipment exists using this principle. Only laboratory prototypes exist.

REFERENCES (See ACOUSTICAL PARTICLE COUNTER in Volume II)

A. Principle of Operation: 249, 349, 6

B. Applications: 250, 349, 2

C. Data: 250, 349

D. Specific Instrument Descriptions: 249, 349

DISCUSSION

A. Advantages

1. Sensitive to single particles.
2. Measures suspended particles without first depositing them.

B. Disadvantages

1. Not sensitive to particle mass, but to particle number concentration.
2. Not sensitive to particles below 5 μm.
3. Has not been made to work reliabily in the laboratory and would need much more development for stack use.
4. Requires low particle concentrations to prevent coincidence errors.

5. Physical principles poorly understood.

6. Requires sampling probe and is subject to probe loss errors.

7. Requires conditioning of the sample stream.

C. Recommendation for Further Development

We recommend no development of this technique for particle monitoring in smoke stacks.

D. Conclusions

Acoustical particle counting is not a practical method for monitoring particles in smoke stacks, primarily because of the first three disadvantages listed earlier.

ACOUSTICAL PARTICLE COUNTER

PRINCIPLE OF OPERATION

Particles cause an audible "click" when passing through or leaving a laminar capillary. The intensity of the "click" is somewhat related to particle size, but the exact relationship is not yet known. Although the phenomena is not very well understood, it can be used to count individual particles. Particles below 5 μm cannot be detected. The resulting measurement is the number concentration of particles above 5 μm.

COMMERCIAL EQUIPMENT

No commercial equipment exists using this principle. Only laboratory prototypes exist.

REFERENCES (See ACOUSTICAL PARTICLE COUNTER in Volume II)

A. Principle of Operation: 249, 349, 6

B. Applications: 250, 349, 2

C. Data: 250, 349

D. Specific Instrument Descriptions: 249, 349

DISCUSSION

A. Advantages

1. Sensitive to single particles.
2. Measures suspended particles without first depositing them.

B. Disadvantages

1. Not sensitive to particle mass, but to particle number concentration.
2. Not sensitive to particles below 5 μm.
3. Has not been made to work reliabily in the laboratory and would need much more development for stack use.
4. Requires low particle concentrations to prevent coincidence errors.

5. Physical principles poorly understood.
6. Requires sampling probe and is subject to probe loss errors.
7. Requires conditioning of the sample stream.

C. Recommendation for Further Development

We recommend no development of this technique for particle monitoring in smoke stacks.

D. Conclusions

Acoustical particle counting is not a practical method for monitoring particles in smoke stacks, primarily because of the first three disadvantages listed earlier.

ALPHA AND GAMMA RADIATION ATTENUATION

PRINCIPLE OF OPERATION

As with beta radiation, alpha and gamma radiation are also attenuated when passing through a medium. Alpha radiation particles, which are really helium nuclei, are not very energetic. A piece of ordinary paper stops most of them. Gamma radiation is an electromagnetic wave with characteristics identical to those of x-rays of the same energy. Gamma radiation can have either high or low energy, depending on the source. The attenuation of gamma radiation, particularly low-energy gamma radiation, depends strongly on the atomic number of the target material. High energy gamma radiation is not appreciably attenuated by thin layers of particles. Alpha and gamma radiation have not been used much to sense particles.

COMMERCIAL EQUIPMENT

No commercial equipment of this type exists.

REFERENCES (See BETA RADIATION ATTENUATION in Volume II)

Few references discuss using alpha and gamma radiation for monitoring particles. Reference 1085 discusses the use of gamma radiation to measure the ash content of coal.

DISCUSSION

A. Advantages

1. No significant advantages as compared to beta radiation attenuation.

B. Disadvantages

1. Not sensitive to particle mass concentration, very sensitive to particulate composition.
2. Alpha radiation is not energetic enough to penetrate reasonable particle deposits.
3. Gamma radiation penetrates large thicknesses of particles with almost no attenuation and, therefore, has poor sensitivity.
4. Gamma radiation is dangerous if not carefully handled and would require careful shielding.
5. Requires sampling probe and is subject to probe loss errors.

6. Requires particle deposition.
7. Requires conditioning of the sample stream.
8. Requires an automatic advancing mechanism for the sample deposit.
9. Not available commercially.

C. Recommendations for Further Development

We recommend no further development for particle monitoring at this time.

D. Conclusions

Alpha and gamma radiation attenuation have no significant advantages over beta radiation attenuation for particle monitoring in stacks. On the other hand, each has several severe disadvantages compared with beta radiation attenuation. Alpha and gamma radiation attenuation cannot be used for monitoring effluent particle mass concentration.

COLLECTION OF PARTICLES IN LIQUID SUSPENSIONS

PRINCIPLE OF OPERATION

If airborne particles are collected into a liquid, the concentration of the resulting suspension is proportional to the original aerosol concentration. This technique can be used for concentrating particles from a large volume of air into a small volume of liquid. Particle collectors include impactors, electrostatic precipitators, cyclones, and bubblers. Particle sensing techniques include light transmission, light scattering, and electrical resistivity.

COMMERCIAL EQUIPMENT

No equipment is known which is designed specifically for automatic monitoring of this type. However, several samplers are available which deposit or collect the particles directly into the liquid. Also, several particle concentration monitors for liquid suspensions are available. A combination of a sampler and sensor should be very easy to assemble since each can operate nearly independent of the other. Samplers which collect particles directly into liquid are:

1. Common bubbler samplers sold by a number of companies.
2. Impaction and electrostatic precipitation samplers particularly suited to this application are manufactured by:

   Litton Systems, Inc.
   Applied Science Division
   13010 County Road 6
   Minneapolis, Minnesota 55427

   Environmental Research Corporation
   3725 North Dunlap Street
   St. Paul, Minnesota 55112

Sensors which measure the concentration and/or the size distribution of particles in a liquid suspension are sold by a number of companies.

REFERENCES

No references have been found which discuss this specific technique. A large number of references discuss the two components of this technique: the particle collector and the liquid suspension sensor.

DISCUSSION

A. Advantages

1. Because some samplers which leave the particles in liquid suspension operate at high air flow rates, they can collect large samples in a short time.

2. The liquid suspension acts as a particle concentrator, allowing the measurement of a wide range of airborne particle concentrations.

3. Several different collectors and sensors can be used.

4. The particle size distribution can be obtained by the same or a similar method.

B. Disadvantages

1. Liquid particles are lost in the liquid suspension.

2. Solid particles may change their shape, size, surface characteristics, etc., when placed in a liquid.

3. Sensing techniques do not measure particle mass and generally share the same problems as their aerosol counterparts.

4. Requires sampling probe and is subject to probe loss errors.

5. Requires the particles to become wetted and remain in liquid suspension until sensed.

6. Requires liquid handling system, probably including recirculation.

C. Recommendations for Further Development

We do not recommend further development of this technique for particle mass concentration measurements at this time.

D. Conclusions

This technique is not a practical method for monitoring the mass concentration of particles in smoke stacks, primarily becuase of the first three disadvantages listed earlier.

CONDENSATION NUCLEI COUNTER

PRINCIPLE OF OPERATION

If an aerosol of 0.002 - 0.1 μm particles with water vapor is suddenly expanded, the water vapor condenses on most particles causing them to grow. Such particles are called condensation nuclei. Depending on the thermodynamic properties of the system, particles larger than about 20 Å grow while smaller particles do not. After sufficient growth, most particles are in the 0.1 to 1.0 μm size range and are quite uniform in size, composition, and optical properties. A photometer then senses the concentration of the resulting aerosol. The measurement can be calibrated in terms of particle number concentration. The measurement is overwhelmingly dominated by submicron particles which do not contain much mass.

COMMERCIAL EQUIPMENT

At least three companies manufacture condensation nuclei counters:

Environment/One Corporation
2773 Balltown Road
Schenectady, New York 12309

General Electric Company
P. O. Box 43
Schenectady, New York 12301

Singco Inc.
11 Cypress Drive
Burlington, Massachusetts 01813

REFERENCES

A. Principle of Operation: 1133, 683

B. Applications: 1133, 27, 42, 68, 683, 606

C. Data: 1133, 336, 683, 606

D. Specific Instrument Descriptions: 1133, 336, 683, 606

DISCUSSION

A. Advantages

1. Measures suspended particles without first depositing them.

2. Fast response, several measurements per second.

3. Readout is easy to record.

4. Sensitive to submicron particles (see disadvantages).
5. Several commercial automatic instruments available.

B. Disadvantages

1. Measurement of number concentration does not correlate with mass concentration.
2. The number of submicron particles to which this instrument is sensitive fluctuates strongly in most effluents.
3. Requires sampling probe and is subject to probe loss errors.
4. Probably requires conditioning of the sample stream.
5. Calibration of present instrument does not appear to remain constant.
6. Some particles may not allow condensation and will therefore not be sensed.

C. Recommendations for Further Development

We recommend no development of this technique as a particle mass concentration monitor. Some development as a research tool for specialized applications may be justified.

D. Conclusions

This technique cannot measure the mass concentration of airborne particles. The measurement is much too sensitive to submicron particles to correlate with particle mass. Some specialized research applications of this technique to stack effluent measurements may exist.

FILTER PRESSURE DROP

PRINCIPLE OF OPERATION

When particle-laden air is passed through a clean filter, the collection of particles on the filter will cause an increase in the pressure differential across the filter. This is because the particles reduce the effective flow area through the filter, which has the same effect as a constriction in a tube.

This technique measures the particle concentration in an airstream if the pressure drop across a filter is monitored as a function of time. This technique does not sense the mass of the particles. It is rather sensitive to the size and shape of the particles. Its particle-size dependence arises because the size (or cross-sectional area) of a particle determines the amount of air flow it "blocks". The shape of the particle determines its ability to penetrate the filter, and, if a particle is allowed to penetrate to the interior of the filter, its effect will be much less pronounced.

COMMERCIAL EQUIPMENT

No commercial equipment is available which uses this technique to measure particle mass concentration.

REFERENCES

A. Principle of Operation: 136, 482, 674

B. Applications: 482, 674, 932, 1042

C. Data: 482, 915, 932

D. Specific Instrument Descriptions: 225, 482, 921, 1042

DISCUSSION

A. Advantages

1. Insensitive to contamination of apparatus because all particles are collected on the filter.

2. Quite simple to design, construct, and operate.

3. Inexpensive.

4. Present commercial filter tape spot samplers can be adapted quite easily.

B. Disadvantages

1. Does not measure the mass of particles.
2. Theory not developed relating particulate mass loading to pressure drop.
3. Technique is sensitive to particle size and shape to such a degree that changes in these parameters overshadow changes in mass loading.
4. Requires sampling probe and is subject to probe loss errors.
5. Requires particle deposition.
6. May require conditioning of the sample stream.
7. Requires some mechanism for periodically replacing filters.
8. Readout not instantaneous or continuous:

   1 data point every 1 min. - 1 hr.

C. Recommendations for Further Development

We do not recommend further development of this technique at the present time.

D. Conclusions

This technique is not very promising for use in stacks at this time. Although a rugged, practical instrument could easily be fabricated, an accurate reading of particle mass concentration is not possible because the technique is not sensitive to the mass of the particles. Changes in other properties such as size and shape overshadow changes in the mass concentration.

FLAME IONIZATION

PRINCIPLE OF OPERATION

When combustible particles pass through a hot flame, they will burn, producing a pulse of electrical ions. The intensity of the ion pulse can be sensed with an electrometer, yielding information about particle concentration and particle size. The magnitude of the ion pulse depends on the mass of the particle, but also on the composition. This technique is analogous to the flame photometry technique.

COMMERCIAL EQUIPMENT

No flame ionization instruments are manufactured for monitoring of particles although several companies manufacture gaseous analyzers using flame ionization.

REFERENCES

A. Principle of Operation: 60

B. Applications: 408

C. Data: 54, 60, 289

D. Specific Instrument Descriptions: 54, 289, 408

DISCUSSION

A. Advantages

1. Measures suspended particles without first depositing them.
2. Can probably operate at stack temperatures.
3. Gives size and concentration data continuously.
4. Probably senses a parameter closely related to particle mass if the composition is acceptable and remains constant.

B. Disadvantages

1. Senses only combustible particles, few of which should exist in stack effluents if the process is under control.
2. Even with combustible particles, the particle composition must remain quite constant.
3. Requires sampling probe and is subject to probe loss errors.
4. Equipment may be expensive.

C. Recommendations for Further Development

We do not recommend further development of this technique for particle mass concentration measurement in stacks.

D. Conclusions

This technique is not a practical method for monitoring the mass concentration of particles in smoke stacks, primarily because of the first disadvantage listed earlier. Flame photometry may be a good indicator of the poor burning of combustible materials and could probably be used in this way to help the plant operator adjust the fuel burning efficiency.

FLAME PHOTOMETRY

PRINCIPLE OF OPERATION

When combustible particles pass through a hot flame, they will burn, producing a bright glow. The intensity of the glow can be sensed by a photometer, yielding information about particle concentration and particle size. The amount of light produced depends on the mass of the particle, but also depends on the composition. This technique is analogous to the flame ionization technique.

COMMERCIAL EQUIPMENT

No flame photometers are manufactured for stack monitoring.

REFERENCES

Reference 53 discusses this technique.

DISCUSSION

A. Advantages

1. Measures suspended particles without first depositing them.
2. Can probably operate at stack temperatures.
3. Gives size and concentration data continuously.
4. Probably senses a parameter closely related to particle mass if the composition is acceptable and remains constant.

B. Disadvantages

1. Senses only combustible particles, few of which should exist in stack effluents if the process is under control.
2. Even with combustible particles, the particle composition must remain quite constant.
3. Requires sampling probe and is subject to probe loss errors.
4. Equipment would probably be quite expensive, especially readout equipment.

C. Recommendations for Further Development

We do not recommend further development of this technique for particle mass concentration measurements in stacks.

D. Conclusions

This technique is not a practical method for monitoring the mass concentration of particles in smoke stacks, primarily because of the first disadvantage listed earlier. Flame photometry may be a good indicator of incomplete burning of combustible materials and could probably be used in this way to help the plant operator adjust the fuel burning efficiency.

GAS ADSORPTION

PRINCIPLE OF OPERATION

If a gas is in equilibrium with a solid surface, the concentration of gas molecules in the vicinity of the surface is always greater than the free gaseous phase. This phenomena, known as adsorption, is independent of the nature of the gas and the surface. The amount of gas, usually nitrogen, adsorbed on a surface can be measured very accurately by means of the Brunnauer-Emmett-Teller (BET) method. This technique measures surface area of a sample. For the monitoring of particles in stacks, a sample must be collected by some auxiliary method and then introduced to the BET apparatus: a batch process.

COMMERCIAL EQUIPMENT

No commercial or research equipment is known to exist for measurement of airborne dusts by this technique. Several companies manufacture BET surface measuring apparatus for manual laboratory measurements of collected particles including:

Micromeritics Instrument Corporation
800 Goshen Springs Road
Norcross, Georgia 30071

Perkin-Elmer Corporation
702 G Main Avenue
Norwalk, Connecticut 06852

REFERENCES

Reference 312 suggests this principle for dust measurement. No references discuss actual instruments or data.

DISCUSSION

A. Advantages

1. Directly measures the surface area of the sample very accurately.
2. Surface area measuring apparatus is well developed and commercially developed.

B. Disadvantages

1. Does not measure the mass of particles, correlation with mass is highly questionable since surface area is measured.
2. Technique not tried on stack effluents, feasibility remains to be proven.

3. Automation of the batch process may be difficult.

4. The batch process may require excessive time to complete one measurement.

5. Requires sampling probe and is subject to probe loss errors.

C. Recommendations for Further Development

We recommend no further development of this techique for particulate mass monitoring. However, the technique is useful for accurate particulate surface area measurements. Automation of the batch process would require considerable development.

D. Conclusions

This technique can measure surface area very accurately. Correlation with mass is poor, and the technique must be rejected for that purpose. However, the technique will be useful in a laboratory for surface area measurements of batches of collected effluent particles.

HOT-WIRE ANEMOMETRY

PRINCIPLE OF OPERATION

Output voltage fluctuations of a hot-wire anemometer placed in an airstream with liquid aerosol are primarily caused by two phenomena: transient cooling of the wire by turbulence of the airstream and evaporative cooling resulting from liquid drops which have impacted on the hot wire. If the thermodynamic properties of the liquid and airstream are known, the two effects can be discriminated by electronic filters. The concentration of liquid droplets can be measured by an electronic counter. Droplets below 3 μm are difficult to detect. Solid particles tend to contaminate the hot wire, resulting in erroneous measurements of gas stream velocity and droplet concentration.

COMMERCIAL EQUIPMENT

Several domestic companies manufacture hot-wire or hot-film anemometers:

Thermo-Systems Inc.
2500 North Cleveland Ave.
St. Paul, Minnesota 55113

Datametrics Division
CGS Scientific Corporation
127 Coolidge Hill Road
Watertown, Massachusetts 02172

Two foreign companies also manufacture this equipment:

Disa Elektronik A/S
Herlev Hovedgade 15-17
Herlev, Denmark

Nihon Kagaku Kogyo Co., Ltd.
4168, Yamadashimo
Suita, Osaka, Japan

REFERENCES (See HOT-WIRE ANEMOMETRY in Volume II)

A. Principle of Operation: 79, 10, 798, 39

B. Applications: 14, 799, 1046, 39, 2

C. Data: 14, 830, 10, 799, 39, 2

D. Specific Instrument Descriptions: 224, 830, 14, 799, 39

DISCUSSION

A. Advantages

1. Can discriminate liquid droplets from solid droplets.
2. Does not require extraction of a sample from the airstream.
3. Can be calibrated to measure droplet size distribution.
4. Several commercial anemometers for air velocity and turbulence measurements have existed for over 10 years.

B. Disadvantages

1. Cannot sense particle mass concentration.
2. Cannot sense solid particles.
3. Cannot sense droplets below 3 μm.
4. Droplet size calibration is only valid if all droplets are the same material.
5. Present hot wires and hot films needed for droplet sensing are somewhat fragile for continuous stack use.

C. Recommendations for Further Development

We recommend no further development for particle monitoring in smoke stacks.

D. Conclusions

Hot-wire and hot-film anemometers cannot be used for monitoring particle mass concentration because of the five listed disadvantages.

PRESSURE DROP IN NOZZLE

PRINCIPLE OF OPERATION

As a gas stream passes through a nozzle, the gas flow rate can be calculated using the well-known relationship between pressure drop and velocity. The presence of particles in the gas stream changes this relationship because the particles lag behind during the rapid velocity changes of the gas stream. Thus, the pressure drop across a nozzle increases if particles are present. The magnitude of the effect caused by particles depends on particle size. Dust concentration of 500 g/m^3 or more are necessary, making it necessary to enrich the concentration of effluent dusts by a factor of at least 1000 in order to measure the concentration with any degree of accuracy.

COMMERCIAL EQUIPMENT

No equipment specifically designed for particle concentration measurement appears to be available. Numerous companies sell nozzles for measureing the flow rate of gas through a tube.

REFERENCES (See PRESSURE DROP IN NOZZLES in Volume II)

A. Principle of Operation: 1067, 225, 1031

B. Applications: 1031, 1067, 225

C. Data: 225, 1031, 1067

D. Specific Instrument Descriptions: 1067

DISCUSSION

A. Advantages

1. Measures suspended particles without first depositing them.
2. Uses simple apparatus which is familiar to most technical people.
3. Reliability of apparatus should be high.
4. Can operate at stack temperatures.

B. Disadvantages

1. Cannot sense particle mass concentration.

2. Cannot sense particle concentrations below 500 g/m^3, requiring particle enrichment of at least 1000 times for stack effluents. Since cyclones are too erratic, no useable enricher is presently known.

3. Requires sampling probe and is subject to probe loss errors.

4. Measurement depends on particle size.

5. Very litle development has been done on this technique.

C. Recommendations for Further Development

We recommend no further development for particle monitoring in smoke stacks.

D. Conclusions

Pressure drop across a nozzle cannot be used for monitoring particle mass concentration, primarily because of the second disadvantage listed above.

RADIOACTIVE TAGGING AND SENSING

PRINCIPLE OF OPERATION

It may be possible to tag airborne particles radioactively so that the activity level is proportional to particle concentration. An activity meter downstream of the "charger" would monitor the activity of the airborne cloud or of the collected (and, thus, concentrated) sample.

COMMERCIAL EQUIPMENT

No instrument of this type is presently available. No reports of research on this technique have been found by the authors.

REFERENCES

No direct references have been found by the authors. Reference 920 discusses some aspects of radioactively labeled aerosols.

DISCUSSION

A. Advantages

1. May offer possibility of monitoring aerosols without first collecting the particles on a surface.

B. Disadvantages

1. Probably would be more proportional to surface area than to mass of particles.
2. Feasibility is not proven, no development has been done.
3. Probably requires sampling probe and is subject to probe less errors.
4. May not operate with stack concentrations.

C. Recommendations for Further Development

We recommend no further development of this technique for particulate mass monitoring unless some radioactive tagging technique is available which places activity on the particles proportional to their mass.

D. Conclusions

Since no feasibility has been done on this technique, it must be rejected for the present. Further evaluation awaits such a study. It appears that this technique would not measure particulate mass but some other particle parameter.

VOLUME MEASUREMENT

PRINCIPLE OF OPERATION

The volume occupied by particles can be measured by several methods. For example, particles collected by a cyclone can settle into a small diameter tube (about 1 mm diameter). The volume of the sample can be measured by monitoring the height of the deposit in the tube after a specified time with a light beam. Another way to measure the sample volume is to measure the amount of liquid needed to fill the tube which holds the particles. Other particle collection and volume measuring techniques can be used.

This technique offers greater promise than most techniques which do not directly sense particulate mass because the volume concentration is related to mass concentration by knowledge of only one other parameter: the average specific gravity of the particles. Most other techniques which do not directly sense mass also require knowledge of the size distribution and other particulate parameters. Unfortunately, average specific gravity of combustion effluent particles fluctuates strongly.

COMMERCIAL EQUIPMENT

No commercial or research instruments of this type are known to exist.

REFERENCES

No references have been found describing this technique.

DISCUSSION

A. Advantages

1. Measures some form of particle volume, a parameter related to mass if one knows particle specific gravity.
2. Principle is simple and easy to analyze for errors.
3. Apparatus could be moderately simple.
4. Time resolution should be quite good, probably about 1 minute per measurement with a cyclone collector.
5. Several particle collectors and sensors can be used, offering the designer greater flexibility in developing instruments.

B. Disadvantages

1. Does not measure particulate mass directly.

2. Particle specific gravity must be known and should be constant for all volume sensing techniques; particle specific gravity within stacks is not well known at this time and may vary considerably with slight plant operating changes.

3. Some volume sensors require knowledge of the packing of the dry deposit, others require a rather complicate liquid-batch process.

4. Readout not instantaneous or continuous:
   1 data point every 1 - 10 minutes.

5. Time required for 1 - 10 micron particles to settle into a chamber may increase the time required for each measurement.

6. Requires particle collection and cleaning of the system for every measurement.

7. No development of this technique appears to have been done although the technique simply combines several well-known procedures.

8. Automation may be difficult.

9. Requires sampling probe and is subject to probe loss errors.

10. May require some conditioning of the sample stream.

C. Recommendations for Further Development

We recommend no development of this technique at this time. The major design problem with this technique appears to be the automation of the system.

D. Conclusions

This technique offers some promise of accurate particulate mass concentration measurements if the specific gravity of the effluent particles remains constant. Unfortunately, the particulate specific gravity within combustion effluents fluctuates quite strongly. Since no instruments of this type have been developed, considerable work remains for development of a reliable instrument. The technique does not measure particulate mass concentration directly and has several other problems listed above. Commercial development would require several years, primarily for the design of the automatic features.

REFERENCES

1 Quenzel, H., "Influence of Refractive Index on the Accuracy of Size-Determination of Aerosol Particles with Light-Scattering Aerosol Counters", *Applied Optics*, V. 8, no. 1, p. 165-169 (Jan 1969).

2 Reist,P.C.,and Burgess, W. A., "A Comparative Evaluation of Three Aerosol Sensing Methods", *American Industrial Hygiene Association Journal*, V. 29, p. 123-128 (Mar - Apr 1968).

3 Fourney, M. E., Matkin, J. H., and Waggoner, A. P., "Aerosol Size and Velocity Determination via Holography", *Review of Scientific Instruments*, V. 40, no. 2, p. 205-213 (Feb 1969).

4 Beck, M. S., Drane, J., Plaskowski, A., and Wainwright, N., "Particle Velocity and Mass Flow Measurement in Pneumatic Conveyors", *Powder Technology*, V. 2, p. 269-277 (1968-1969).

5 Soo, S. L., Stukel, J. J., and Hughes, J. M., "Measurement of Mass Flow and Density of Aerosols in Transport", *Environmental Science and Technology*, V. 3, no. 4, p. 386-392 (Apr 1969).

6 Langer, G., "Status of Acoustic Particle Counter Research", *Powder Technology*, V. 2, p. 307-309 (1968-1969).

7 Hyzer, W. G., "Hyzer on High Speed", *Photo Methods for Industry* (1970).

8 Whitby, K. T., and McFarland, A. R., "Electrical Measurement of the Mass Concentration of a Self-Preserving Aerosol Size Distribution", *APCA Journal*, V. 18, no. 11, p. 760-764 (Nov 1968).

9 Cartan, F. O., and Curtis, G. J., "New Rapid Method for Average Particle Size Measurement" *Analytical Chemistry*, V. 41, no. 12, p. 1719-1720 (Oct 1969).

10 Goldschmidt, V. W., and Householder, M. K., "The Hot Wire Anemometer as an Aerosol Droplet Size Sampler", *Atmospheric Environment*, V. 3, p. 643-651 (1969).

11 Westlin, K. and Czerwonka, J., "Sampling and Analysis of Industrial Process Dust" *American Industrial Hygiene Association Quarterly*, V. 16, no. 4, (Dec 1955).

12 Anon, "Particulate Controls: A Must to Meet Air Quality Standards", *Environmental Science and Technology*, V. 3, no. 11, p. 1149-1151 (Nov 1969).

13 Lucas, D. H., "I. Air Pollution Measurements", *Phil. Trans. Royal Society of London*, V. A257, p. 143-151 (1969).

14 Goldschmidt, V. W., "Measurement of Aerosol Concentrations with a Hot Wire Anemometer", *Journal of Colloid Science*, V. 20, p. 617-634 (1965).

15 Schleusener, S. A. "Automatic High Speed Particle Sizing Using a Gas Laser", *Review of Scientific Instruments*, V. 39, no. 12, p. 1916-1919 (Dec 1968).

16 Anon, "Particle Counting Technology", *Contamination Control*, p. 11-25 (Jan 1969).

17 Meland, B. R., "A Comparative Study of Particulate Loadings in Plumes Using Multiple Sampling Devices", *APCA Journal*, V. 18, no. 8, p. 529-533 (Aug 1968).

18 Cooney, J., Orr, J., and Tomasetti, C., "Measurements Separating the Gaseous and Aerosol Components of Laser Atmospheric Backscatter", *Nature*, V. 224, p. 1098-1099 (Dec 1969).

19 Megaw, W. J., and Wells, A. C., "A High Resolution Charge and Mobility Spectrometer for Radioactive Submicrometre Aerosols", *Journal of Scientific Instruments, Journal of Physics E.*, Series 2, Vol. 2, p. 1013-1016 (1969).

20 Cheng, L., Tung, S. K., and Soo, S. L., "Electrical Measurement of Flow Rate of Pulverized Coal Suspension", *ASME Paper No. 69-WA/Pwr-1*, 14 p. (1969).

21 Horstman, S. W., and Wagman, J., "Size Analysis of Acid Aerosols by a Metal Film Technique", *American Industrial Hygiene Association Journal*, V. 28, p. 523-530 (Nov - Dec 1967).

22 Yamamoto, G., and Tanaka, M., "Determination of Aerosol Size Distribution from Spectral Attenuation Measurements", *Applied Optics*, V. 8, no. 2, p. 447-454 (Feb 1969).

23 Hamilton, P. M., "Lidar Measurement of Backscatter and Attenuation of Atmospheric Aerosol", *Atmospheric Environment*, V. 3, p. 221-223 (1969).

24 Flesch, J. P., "Calibration Studies of a New Sub-Micron Aerosol Size Classifier", *Journal of Colloid and Interface Science*, V. 29, no. 3, p. 502-509 (Mar 1969).

25 Bell, J. H., "Particle Size Determination", Manufacturing Chemist and Aerosol News, p. 74 (Nov 1968).

26 Adams, J. M., "Light Extinction Photometer for Measurement of Particle Sizes in Polydispersions", Review of Scientific Instruments, V. 39, no. 11, p. 1748-1751 (Nov 1968).

27 Peterson, C. M., and Paulus, H. J., "Continuous Monitoring of Aerosols Over the 0.001- to 10-Micron Spectrum", American Industrial Hygiene Association Journal, p. 111-122 (Mar - Apr 1968).

28 McFarland, A. R., et al, "Aerosol Research In Progress" APCA Journal, V. 18, no. 10, p. 651-696 (Oct 1968).

29 Lundgren, D. A., "An Aerosols Sampler for Determination of Particle Concentration as a Function of Size and Time", APCA Journal, Vol. 17, no. 4, p. 225-229 (Apr 1967).

30 Bascomb, C. L., "A New Apparatus for Recording Particle Size Distribution", Journal of Sedimentary Petrology, V. 38, no. 3, p. 878-884 (Sep 1968).

31 Parker, C. J., "Some Factors Governing the Design of Probes for Sampling in Particle- and Drop-Laden Streams", Atmospheric Environment, V. 2, p. 477-490 (1968).

32 Preining, O., "The Cross Sensitivities of the Royco Aerosol Photometer PC 200", Staub-Reinhalt der Luft (Engl. Trans.), no. 1, p. 29-32 (Jan 1968).

33 Allen, T., "Determination of the Size Distribution and Specific Surface of Fine Powders by Photo-extinction Methods. I. Theoretical Estimate of Variation in Extinction Coefficient with Particle Size Using a White Light Source", Powder Technology, V. 2, p. 133-140 (1968-69).

34 Allen, T., "Determination of the Size Distribution and Specific Surface of Fine Powders by Photo-extinction Methods. II. Comparison between Wide-Angle and Narrow-Angle Photosedimentometers and Experimental Determination of Extinction Coefficients", Powder Technology, V. 2, p. 141-153 (1968-69).

35 Leschonski, K., and Rumpf, H., "Principle and Construction of Two New Air Classifiers for Particle Size Analysis", Powder Technology, V. 2, p. 175-185 (1968-69).

36 Stober, W., and Flachsbart, H., "Aerosol Size Spectrometry with a Ring Slit Conifuge", Environmental Science and Technology, V. 3, no. 7, p. 641-651 (Jul 1969).

37 Rozenberg, G. V., "Optical Investigations of Atmospheric Aerosols", Soviet Physics Uspekhi (Engl. Trans.), V. 11, no. 3, p. 353-380 (Nov - Dec 1968).

38 Livesey, P. J., and Billmeyer, F. W., Jr., "Particle-Size Determination by Low-Angle Light Scattering: New Instrumentation and a Rapid Method of Interpreting Data", Journal of Colloid and Interface Science, V. 30, no. 4, p. 447-472 (Aug 1969).

39 Goldschmidt, V. W., "Measurement of Aerosol Concentrations with a Hot Wire Anemometer", 39th Nat. Colloid Symposium, Div. of Colloid and Surface Chemistry, Am. Chem. Soc. Clarkson College of Technology, Potsdam, N.Y., June 21-23, 1965, p. 192-208 (1965).

40 Liu, B.Y.H., Marple, V. A., and Yazdani, H., "Comparative Size Measurements of Monodisperse Liquid Aerosols by Electrical and Optical Methods", Environmental Science and Technology, V. 3, no. 4, p. 381-386 (Apr 1969).

41 Raabe, O. G., "Concerning the Interactions That Occur Between Radon Decay Products and Aerosols", Health Physics, V. 17, p. 177-185 (1969).

42 Clark, W. E., and Whitby, K. T., "Concentration and Size Distribution Measurements of Atmospheric Aerosols and a Test of the Theory of Self-Preserving Size Distributions", Journal of Atmospheric Sciences, V. 24, no. 6, p. 677-687 (Nov 1967).

43 Herrick, R. A., and Benedict, L. G., "A Microscopic Classification of Settled Particulates Found in the Vicinity of a Coke-Making Operation", APCA Journal, V. 19, no. 5, p. 325-328 (May 1969).

44 Hochrainer, D., and Brown, P. M., "Sizing of Aerosol Particles by Centrifugations", Environmental Science and Technology, V. 3, no. 9, p. 830-835 (Sep 1969).

45 Boyce, M. P., and Blick, E. F., "Fluid Flow Phenomena in Dusty Air", ASME Paper No. 69-WA/FE-24, 11 p, (1969).

46 Harris, G. W., "A Laboratory Instrument for Measuring the Turbidity of a Suspension of Dust Particles", Powder Technology, V. 3, p. 107-111, (1969-70).

47 Anon, "Particle Size Analysis in the Sub-Micron Range", Control & Instrumentation, p. 63-65 (May 1969).

48 Schleusener, S. A., "A Gas Laser Aerosol Detection and Sizing Instrument", APCA Journal, V. 19, no. 1, p. 40-42 (Jan 1969).

49 Smith, B. M., and Wagman, J., "Interaction of Airborne Particles with Gases", Environmental Science and Technology, V. 3, no. 6, p. 558-562 (Jun 1969).

50 Elfers, L. A., and Decker, C. E., "Determination of Fluoride in Air and Stack Gas Samples by Use of an Ion Specific Electrode", *Analytical Chemistry*, V. 40, no. 11, p. 1658-1661 (Sep 1968).

51 Fuchs, N. A., and Sutugin, A. G., "Coagulation Rate of Highly Dispersed Aerosols", *Journal of Colloid Science*, V. 20, p. 492-500 (1965).

52 Zebel, G., "Deposition of Aerosol Flowing Past a Cylindrical Fiber in a Uniform Electric Field", *Journal of Colloid Science*, V. 20, p. 522-543 (1965).

53 Crider, W. L., "Spectrothermal Emission Aerosol Particle Analyzer (SEAPA)", *Review of Scientific Instruments*, V. 39, no. 2, (Feb 1968).

54 Crider, W. L., and Strong, A. A., "Flame Ionization-Pulse Aerosol Particle Analyzer (FIPAPA)", *Review of Scientific Instruments*, V. 38, no. 12, p. 1772-1775 (Dec 1967).

55 Liu, B.Y.H., and Yeh, H. C., "On the Theory of Charging of Aerosol Particles in a Electric Field", *Journal of Applied Physics*, V. 39, no. 3, p. 1396-1402 (Feb 1968).

56 Liu, B.Y.H., Whitby, K. T., and Yu, H.H.S., "On the Theory of Charging of Aerosol Particles by Unipolar Ions in the Absence of an Applied Electric Field", *Journal of Colloid & Interface Science*, V. 23, p. 367-387 (1967).

57 Coutarel, L., Matijevic, E., Kerker, M., and Huang, C.M., "Aerosol Studies by Light Scattering, VI. Preparation and Growth of Sulfuric Acid Aerosols", *Journal of Colloid and Interface Science*, V. 24, p. 338-343 (1967).

58 Takahashi, K., and Iwai, S., "Estimation of Size Distribution of Small Aerosol Particles by Light-Scattering Measurements", *Journal of Colloid & Interface Science*, V. 23, p. 113-119 (1967).

59 Thompson, B. J., Ward, J. H., and Zinky, W. R., "Application of Hologram Techniques for Particle Size Analysis", *Applied Optics*, V. 6, no. 3, p. 519-526 (Mar 1967).

60 Ohline, W. R., "Hydrogen Flame Ionization for the Detection and Sizing of Organic Aerosols", *Analytical Chemistry*, V. 37, no. 1, p. 93-96 (Jan 1965).

61 Whitby, K. T., and Peterson, C. M., "Electrical Neutralization and Particle Size Measurement of Dye Aerosols", *Industrial & Engineering Chemistry Fundamentals*, V. 4, no. 1, p. 66-72 (Feb 1965).

62 Derjaguin, B. V., Yalamov, Y. I., and Storozhilova, A. I., "Diffusiophoresis of Large Aerosol Particles", Journal of Colloid & Interface Science, V. 22, p. 117-25 (Aug 1966).

63 Low, M.J.D., and Clancy, F. K., "Remote Sensing and Characterization of Stack Gases by Infrared Spectroscopy", Environmental Science & Technology, V. 1, no. 1, p. 73-74 (Jan 1967).

64 Rossano, A. T., and Cooper, H.B.H., "Sampling and Analysis", Chemical Engineering, V. 75, no. 22, p. 142-146 (Oct 1968).

65 Kitani, S., and Ouchi, S., "Preparation of Monodisperse Aerosols of Sodium Chloride", Journal of Colloid & Interface Science, V. 23, p. 200-202, (1967).

66 Johnson, W. B., "Lidar Applications in Air Pollution Research and Control", APCA Journal, V. 19, no. 3, p. 176-180 (Mar 1969).

67 Decker, H. M., Buchanan, L. M., Frisque, D., Filler, M.E., and Dahlgren, C. M., "Advances in Large-Volume Air Sampling", Contamination Control, p. 13-17 (Aug 1969).

68 Whitby, K. T., and Clark,W. E., "Electric Aerosol Particle Counting and Size Distribution Measuring System for the 0.015 to 1 μ Size Range", Tellus, V. 18, p. 573-586 (1966).

69 Charlson, R. J., "Atmospheric Visibility Related to Aerosol Mass Concentration, A Review", Environmental Science & Technology, V. 3, no. 10, p. 913-918 (Oct 1969).

70 Kerker, M., Farone, W. A., Smith, L. B., and Matijevic, E., "Determination of Particle Size by the Minima and Maxima in the Angular Dependence of the Scattered Light, Range of Validity of the Method", Journal of Colloid Science, V. 19, p. 193-200 (Mar 1964).

71 Kerker, M., Matijevic, E., Espenscheid, W. F., Farone, W. A., and Kitani, S., "Aerosol Studies by Light Scattering. I. Particle Size Distribution by Polarization Ratio Method", Journal of Colloid Science, V. 19, p. 213-222 (Mar 1964).

72 Matijevic, E., Kitani, S., and Kerker, M., "Aerosol Studies by Light Scattering. II. Preparation of Octanoic Acid Aerosols of Narrow and Reproducible Size Distributions", Journal of Colloid Science, V. 19, p. 223-237 (Mar 1964).

73 Litvinov, A. T., "Determination of the Dynamic Shape Factor and Apparent Density of Nonspherical Aggregated Particles in Aerosols Containing a Solid Disperse Phase", Colloid Journal of USSR (Engl. Trans), V. 30, no. 2, p. 228-231 (Mar - Apr 1968).

74 Connor, P., "Automatic Counting and Sizing of Particles", Industrial Chemist, V. 39, no. 2, p. 69-74 (Feb 1963).

75 Plumley, A. L., Jonakin, J., Martin, J. R., and Singer, J. G., "Removal of SO_2 and Dust from Stack Gases", Combustion, V. 40, no. 1, p. 16-23 (Jul 1968).

76 Prince, L. H., and Clarenburg, L. A. "Device for Continuous Isokinetic Aerosol Sampling", Review of Scientific Instruments, V. 34, no. 7, p. 742-744 (Jul 1963).

77 Seiler, E., "Design for Air Pollution Control - Stack Analysis for Sampling" Air Conditioning, Heat. & Vent., V. 65, no. 2, p. 8, 10, 12 (Feb 1968).

78 Frankenberg, T. T., and Perry, H., "Air Pollution from Power Plants and Its Control", Combustion, V. 34, no. 8, p. 28-33 (Feb 1963)

79 Golovin, M. N., and Putnam, A. A., "Inertial Impaction on Single Elements", Indust. & Eng. Chem. Fundamentals", V. 1, no. 4, p. 264-273 (Nov 1962).

80 Langer, G., Radnik, J., and Templeton, L., "Development of a Simple, High-Resolution Mobility Analyzer for Small, Charged Particles", Review of Scientific Instruments, V. 33, no. 1, p. 83-84 (Jan 1962).

81 Air Pollution Research - Progress Summary, July 1, 1967 - June 30, 1968 - Project Staff, University of California, Los Angeles, Clearinghouse No. PB 180 953 (1968).

82 Anon, Air Pollution and the Regulated Electric Power & Natural Gas Industries, Federal Power Comm., Washington, D. C., Clearinghouse No. PB 180 207 (Sep 1968).

83 Brief, R. S. "Air Pollution from Stacks", Air Conditioning Heating & Ventilating, p. 61-66 (Jul 1965).

84 Meddle, D. W., and Wood, R., "Apparatus for Preparing Standard Aerosol Atmospheres", Chem. & Industry, no. 47, p. 1635-1637 (Nov 1968).

85 Hodkinson, J. R., "Particle Sizing by Means of the Forward Scattering Lobe", Applied Optics, V. 5, no. 5, p. 839-844 (May 1966).

86 Grune, W. N., "Analysis by Gas Chromatography", Indus. Water & Wastes, V. 7, no. 2, 3, p. 29-36 (Mar-Apr 1962).

87 Niemeyer, L. E., and Schiermeier, F. A., "Tall Stack Study Underway", Power Engineering, V. 73, no. 2, p. 42-45 (Feb 1969).

88 Bolduc, M. J., and Severs, R. K. "Modified Total Combustion Analyzer for Use in Source Testing Air Pollution", Air Engineer, V. 7, no. 8, p. 26-29 (Aug 1965).

89 Cooper, D. W., and Byers, R. L., "Laser Light Backscattering from Laboratory Aerosols", APCA Journal, V. 20, no. 1, p. 43-47 (Jan 1970).

90 Gross, D., Loftus, J. J., and Robertson, A. F., "Methods for Measuring Smoke from Burning Materials", ASTM Special Technical Publication 422, p. 166-204 (1969).

91 Ubbelohde, A. R., "Discussion on Science and Technology of Aerosol Pollution, Introductory Remarks", Proc. Royal Soc., V. A307, no. 1489, p. 139-140 (Oct 1968).

92 Weinberg, F. J., "Electrical Aspects of Aerosol Formation and Control", Proc. Royal Soc., V. A307, no. 1489, p. 195-208 (Oct. 1968).

93 Homann, K. H., and Wagner, H. G., "Chemistry of Carbon Formation in Flames", Proc. Royal Soc., V. A307, p. 141-152 (1968).

94 Agnew, W. G., "Automotive Air Pollution Research", Proc. Royal Soc., V. A307, p. 153-181 (1968).

95 Burt, R., and Thomas, A., "Aerosol Pollution from Internal Combustion Engines", Proc. Royal Soc., p. 183-194 (1968).

96 Stairmand, C. J., "Some Industrial Problems of Aerosol Pollution", Proc. Royal Soc., V. A307, p. 209-214 (1968).

97 Wilson, M.J.G., "Indoor Air Pollution", Proc. Royal Soc., V. A307, p. 215-221 (1968).

98 Lawther, P. J., Ellison, J. McK., and Waller, R. E., "Some Medical Aspects of Aerosol Research", Proc. Royal Soc., V. A307, p. 2230234, (1968).

99 Armistead, R. A., Jr., and Keyes, J.J., Jr., "Hot-Film Sensor for the Study of Wall Turbulence Phenomena", Rev. of Scientific Instruments, V. 39, no. 1, p. 61-68 (Jan 1968).

100 Espenscheid, W. F., Matijevic, E., and Kerker, M., "Aerosol Studies by Light Scattering. III: Preparation and Particle Size Analysis of Sodium Chloride Aerosols of Narrow Size Distribution", Journal of Physical Chemistry, V. 68, p. 2831-2842 (1964).

101 Jacobsen, R. T., Kerker, M., and Matijevic, E., "Aerosol Studies by Light Scattering, V: Preparation and Particle Size Distribution of Aerosols Consisting of Particles Exhibiting High Optical Absorption", Journal of Physical Chemistry, V. 71, p. 514-520 (1967).

102 Espenscheid, W. F., Willis, E., Matijevic, E., and Kerker, M., "Aerosol Studies by Light Scattering, IV: Preparation and Particle Size Distribution of Aerosols Consisting of Concentric Spheres", Journal of Colloid Science, V. 20, p. 501-521 (1965).

103 Dobbins, R. A., and Tempkin, S., "Acoustical Measurements of Aerosol Particle Size and Concentration", Journal of Colloid & Interface Science, V. 25, no. 3, p. 329-333 (Nov 1967).

104 Soo, S. L., Trezek, G. J., Dimick, R. C., and Hohnstreiter, G. F., "Concentration and Mass Flow Distributions in a Gas-Solid Suspension", Industrial & Engineering Chemistry Fundamentals, V. 3, p. 98-106 (1964).

105 Soo, S. L, and Trezek, G. J., "Turbulent Pipe Flow of Magnesia Particles in Air", Industrial & Engineering Chemistry Fundamentals, V. 5, p. 388-392 (1966).

106 Anon, "Particle Size Determination Simplified", Chemical & Eng. News, (Feb 1969).

107 Rosen, J. M., "The Vertical Distribution of Particulate Matter Near the Surface of the Earth", APCA Journal, V. 19, no. 2, p. 106-108 (1969).

108 Cadle, R. D., and Ledford, M., "Reaction of Ozone with Hydrogen Sulfide", Int. J. Air Wat. Poll., V. 10, no. 1, p. 25-30 (Jan 1966).

109 Wagman, J., "Current Problems in Atmospheric Aerosol Research", Int. J. Air Wat. Poll., V. 10, no. 12, p. 777-72 (Nov - Dec 1966).

110 Clough, W. S., Cousins, L. B., and Eggleton, A.E.J., "Radio-Iodine Adsorption on Particulate Matter", Int. J. Air Wat. Poll., V. 9, no. 12, p. 769-789 (Dec 1965).

111 Sawicki, E., Meeker, J. E., and Morgan, M.J., "The Quantitative Composition of Air Pollution Source Effluents in Terms of AZA Heterocyclic Compounds and Polynuclear Aromatic Hydrocarbons", Int. J. Air Wat. Poll., V. 9, no. 5, p. 291-298 (May 1965).

112 Ripley, D. L., Clingenpeel, J. M., and Hurn, R. W., "Continuous Determination of Nitrogen Oxide in Air and Exhaust Gases", Int. J. Air Wat. Poll., V. 8, no. 8-9, p. 455-463 (Sep 1964).

113 Wootten, N. W., "A Method for the Measurement of True Light Absorption in Aerosols", British Journal of Applied Physics., V. 13, no. 8, p. 406-8 (Aug 1962).

114 Flowers, A. E., "Sulfur Question", Coal Age, V. 73, no. 4, p. 71-81 (Apr 1968).

115 Diehl, E. K., Bruel, F. du, Glenn, R. A., "Polynuclear Hydrocarbon Emission From Coal-Fired Installations", ASME - Paper 66 - Pwr.-2, for meeting Sep 18-21, 1966, 7 p.

116 Diehl, E. K., and Zawadzki, E. A., "Contaminants in Flue Gases - and Methods for Removal", Coal Age, V. 70, no. 12, p. 70-74 (Dec 1965).

117 Bragg, L. G., "Gas Flow Model Studies of Flues", Can. Min. & Met. Bul., V. 55, no. 606, p. 707-712 (Oct 1962).

118 Bowden, A. T., Draper, P., and Rowling, H., "The Problem of Fuel-Oil Ash Deposition in Open-Cycle Gas Turbines", American Inst. of Mechanical Engineers Proc., V. 167, p. 291-300 (1953).

119 Twomey, S., "Determination of Aerosol Size Distributions from Diffusional Decay Measurements", Franklin Instn. Journal, V. 275, no. 2, p. 121-138 (Feb 1963).

120 Thomas, A. L.,Jr., Bird, A. N., Jr., Collins, R. H., III, and Rice, P. C., "A Portable Photometer and Particle Size Analyzer", ISA Journal, V. 8, p. 52-56 (Jul 1961).

121 Cohen, I. R., and Altshuller, A. P., "A New Spectrophotometric Method for the Determination of Acrolein in Combustion Gases and in the Atmosphere", Analytical Chemistry, V. 22, p. 726-733 (May 1961).

122 Grindell, D. H., "An Electrostatic Dust Monitor", IEE Proc., Series A (34), V. 107, p. 353 (1960).

123 Goetz, A., and Preining, O., "The Aerosol Spectrometer and Its Application to Nuclear Condensation Studies", Monograph No. 5, Geophysical Union, (1960).

124 Thompson, J. K., "Determination of Aerosol Size Distributions by Jet Impactor-Light Scattering Technique", Analytical Chemistry, V. 29, p. 1847-50 (1957).

125 Sawyer, K. F., and Walton, W. H., "The 'Conifuge' - A Size-Separating Sampling Device for Airborne Particles", Journal of Scientific Instruments, V. 27, p. 272-276 (1950).

126 Reynolds, G. O., and DeVelis, J. B., "Hologram Coherence Effects", IEEE Trans., V. AP-15, p. 41-48 (1967).

127 Min, K., Chao, B. T., and Wyman, M. E., "Measurement of Electrostatic Charge on Solid Particles in Solid Gas Suspension Flow", Review of Scientific Instruments, V. 34, p. 529-531 (1963).

128 Meier, R. W., "Magnification and Third-Order Abberations in Holography", Optical Society of America Journal, V. 55, p. 987-992 (1965).

129 Leith, E., Upatnieks, J., and Haines, K. A., "Microscopy by Wavefront Reconstruction", Optical Society of America Jounral, V. 55, p. 981-986 (1965).

130 Kirkpatrick, P., and El Sum, H.M.A., "Image Formation by Reconstructed Wave Fronts. I: Physical Principles and Methods of Refinement", Optical Society of America Journal, V. 46, p. 825-831 (1956).

131 Gabor, D., "Microscopy by Reconstructed Wavefronts", Proc. Royal Society, V. A197, p. 454-487 (1949).

132 DeVelis, J. B., Parrent, G. B., Jr.,and Thompson, B.J., "Image Reconstruction with Fraunhofer Holograms", Optical Society of America Journal, V. 56, p. 423-427 (1966).

133 Davies, C. N., "Deposition of Aerosols from Turbulent Flow Through Pipes", Proc. Royal Society, V. A289, p. 235-246 (1966).

134 Davies, C. N., "Brownian Deposition of Aerosol Particles from Turbulent Flow Through Pipes", Proc. Royal Society, V. A290, p. 557-562 (1966).

135 Curcio, J. A., "Evaluation of Atmospheric Aerosol Particle Size Distribution from Scattering Measurements in the Visible and Infrared", Optical Society of America Journal, V. 51, p. 548-551 (1961).

136 Whitby, K. T., "Calculation of the Clean Fractional Efficiency of Low Media Density Filters", ASHRAE Journal, V. 7, no. 9, p. 56-65 (Sep 1965).

137 Wallach, M. L., Heller, W., and Stevenson, A. F., "Theoretical Investigations on the Light Scattering of Colloidal Spheres. XII: The Determination of Size Distribution Curves from Turbidity Spectra", Journal of Chemical Physics, V. 34, p. 1796-1802 (1961).

138 Temkin, S., and Dobbins, R. A., "Measurements of Attenuation and Dispersion of Sound by an Aerosol", Journal of the Acoustical Society of America, V. 40, no. 5, p. 1016-29 (Nov 1966).

139 Temkin, S., and Dobbins, R. A., "Attenuation and Dispersion of Sound by Particulate - Relaxation Processes", Journal of the Acoustical Soc. of America, V. 40, no. 2, p. 317-334 (Aug 1966).

140 Stevenson, A. F., Heller, W., and Wallach, M. L., "Theoretical Investigations on the Light Scattering of Colloidal Spheres. XI: Determination of Size Distribution Curves from Spectra of the Scattering Ratio or from Depolarization Spectra", Journal of Chemical Physics, V. 34, p. 1789-1795 (1961).

141 Soo, S. L., Ihrig, H. K., Jr., and El Kouh, A.F., "Experimental Determination of Statistical Properties of Two-Phase Turbulent Motion", Journal of Basic Engineering, Trans.ASME, Series D., V. 82, no. 3, p. 609-621 (1960).

142 Kunkel, W. B., "The Static Electrification of Dust Particles on Dispersion Into a Cloud", Journal of Applied Physics, V. 21, p. 820-832 (Aug 1950).

143 Hodkinson, J. R., and Greenfield, J. R., "Response Calculations for Light-Scattering Aerosol Counters and Photometers", Applied Optics, V. 4, p. 1463-1474 (1965).

144 Heller, W., and Wallach, M. L., "Experimental Investigations on the Light Scattering of Colloidal Spheres. V: Determination of Size Distribution Curves by Means of Spectra of the Scattering Ratio", Journal of Physical Chemistry, V. 67, p. 2577-2583 (1963).

145 Gucker, F. T., Jr., O'Konski, C. T., Pickard, H. B., and Pitts, J.N., Jr., "A Photoelectric Counter for Colloidal Particles", American Chemical Society Journal, V. 69, no. 10, p. 2422-2431 (1947).

146 Gucker, F. T., Jr., and O'Konski, C. T., "An Improved Photoelectric Counter for Colloidal Particles, Suitable for Size-Distribution Studies", Journal of Colloid Science, V. 4, p. 541-(1949).

147 Mie, "Beitrage zur Optik truber medien, speziell kolloidaler Metallosungen", Annalen der Physik, V. 25, no. 3, p. 377-445 (1908).

148 Silverman, B. A., Thompson, B. J., and Ward, J. H., "A Laser Fog Disdrometer", Journal of Applied Meteorology, V. 3, p. 792-801 (1964).

149 Barrett, E. W., and Ben-Dov, O., "Application of the Lidar to Air Pollution Measurements", Journal of Applied Meteorology, V. 6, p. 500-515 (1967).

150 Thompson, B. J., Parrent, G. B., Ward, J. H., and Justh, B., "A Readout Technique for the Laser Fog Disdrometer", Journal of Applied Meteorology, V. 5, p. 343-347 (1966).

151 Bianconi, W., and Thomas, F., "Reproducibility of Aerosol Photometer, Midget Impinger, and Membrane Filter Counts for Limestone and Coal Dusts", American Indust. Hygiene Assoc. Journal, V. 26, p. 363-365 (Jul - Aug 1965).

152 Sehmel, G. A., "A Particle Size Distribution Function for Data Recorded in Size Range", Annals of Occupational Hygiene, V. 11, p. 87-98 (1968).

153 Schumacher, B. W., Wojcik, W., and Zavitz, R.C., "Monitoring System for an Oxygen Steel Furnace Using a Beta-Ray Gauge in the Flame", International Journal of Applied Rad. and Isotopes, V. 13, p. 123-129 (1962).

154 Flesch, J. P., Norris, C. H., and Nugent, A. E., Jr., "Calibrating Particulate Air Samplers with Monodisperse Aerosols: Application to the Andersen Cascade Impactor", American Industrial Hygiene Assoc. Journal, V. 28, no. 6, p. 507-516 (Nov - Dec 1967).

155 Martens, A. E., and Keller, J. D., "An Instrument for Sizing and Counting Airborne Particles", American Industrial Hygiene Assoc. Journal, V. 29, (May - Jun 1968).

156 Halitsky, J., "Estimation of Stack Height Required to Limit Contamination of Building Air Intakes", American Industrial Hygiene Assoc. Journal, V. 26, p. 106-116 (Mar - Apr 1965).

157 Woolrich, D. F., "Methods for Estimating Oxides of Nitrogen Emissions from Combustion Processes", American Industrial Hygiene Assoc. Journal, V. 22, p. 481-484 (Dec 1961).

158 Adams, D. F., Jensen, G. A., Steadman, J. P., Koppe, R. K., and Robertson, T. J., "Improved Sulfur-Reacting Microcoulometric Cell for Gas Chromatography", Analytical Chemistry, V. 38, no. 8, p. 1094-1096 (1966).

159 Brock, J. R., "Some New Modes of Aerosol Particle Motion: Photo-diffusiophoresis", Journal of Physical Chemistry, V. 72, no. 2, p. 747-749 (1968).

160 Galstaun, L.S., Steigerwald, B. J., Ludwig, J. H., and Garrison, H. R., "What Does It Cost to Desulferize Fuel Oil", Chemical Engineering Progress, V. 61, no. 9, p. 49-58 (Sep 1965).

161 Langer, G., "An Acoustic Particle Counter - Preliminary Results", Journal of Colloid Science, V. 20, p. 602-609 (1965).

162 Levy, A., and Merryman, E. L., "Sulfur-Oxide Formation in Carbonyl Sulfide Flames", *Environmental Science & Technology*, V. 3, no. 1, p. 63-68 (Jan 1969).

163 Mercer, W. B., "Calibration of Coulter Counters for Particles $\approx 1\mu$ in Diameter", *Review of Scientific Instruments*, V. 37, no. 11, p. 1515-1520 (1966).

164 Mockros, L. F., Quon, J. E., and Hjelmfelt, A. T., Jr., "Coagulation of a Continuously Reinforced Aerosol", *Journal of Colloid & Interface Science*, V. 23, p. 90-98 (1967).

165 Nakajima, Y., Gotoh, K., and Tanaka, T., "On-Line Particle-Size Analyzer", *Industrial Eng. Chemistry Fundamentals*, V. 6, no. 4, p. 587-592 (1967).

166 Nettleton, M. A., "Burning Rates of Devolatilized Coal Particles", *Industrial & Engineering Chemistry Fundamentals*, V. 6, no. 1, p. 20-25 (Feb 1967).

167 Prince, L. H., "Improved Determination of Calibration and Coincidence Correction Constants for Coulter Counters", *Review of Scientific Instruments*, V. 37, no. 10, p. 1416-1418 (1966).

168 Robins, D. L., and Mattia, M. M., "Computer Program Helps Design Stacks for Curbing Air Pollution", *Chemical Engineering*, V. 75, no. 3, p. 119-122 (Jan 1968).

169 Slater, W. L., and Dille, R. M., "Partial Combustion of Residual Fuels", *Chem. Eng. Progress*, V. 61, no. 11, p. 85-88 (Nov 1965).

170 Takahashi, K., "Determination of Number Concentration of Polydispersed Small Aerosol Particles by Turbidity Measurement", *Journal of Colloid & Interface Science*, V. 24, no. 2, p. 159-163 (1967).

171 Whitby, K. T., and Vomela, R. A., "Response of Single Particle Optical Counters to Nonideal Particles", *Environmental Science & Technology*, V. 1, no. 10, p. 801-814 (1967).

172 Singer, J. M., Cook, E. B., Harris, M. E., Rowe, V. R., and Grumer, J., *Flame Characteristics Causing Air Pollution: Production of Oxides of Nitrogen and Carbon Monoxide*, U. S. Bureau of Mines, Publication RI 6958, 34 p. (1967).

173 Smith, J. F., Hultz, J. A., and Orning, A. A., *Sampling and Analysis of Flue Gas for Oxides of Sulfur and Nitrogen*, U. S. Bureau of Mines, Publication RI 7108, 21 p. (Apr 1968).

174 Kurtzrock, R. C., Bienstock, D., and Field, J. H., "Process Development in Removing Sulfur Dioxide from Hot Flue Gases", U. S. Bureau of Mines, Publication 6307 (1963).

175 Throne, D. J., and Watt, J. D., "Composition and Pozzolanic Properties of Pulverized Fuel Ashes - II.", Journal of Applied Chemistry, V. 15, no. 12, p. 595-604 (1965).

176 Watt, J. D., and Throne, D. J., "Composition and Pozzolanic Properties of Pulverized Flue Ash. I.", Journal of Applied Chemistry, V. 15, no. 12, p. 585-594 (1965).

177 Mueller, G. R., "Charts Determine Gas Temperature Drops in Metal Flue Stacks", Heating, Piping & Air Conditioning, V. 40, no. 1, p. 138-142 (Jan 1968).

178 Monroe, E. S., Jr., "Improving Combustion with Heavy Fuel Oils", Oil & Gas Journal, V. 64, no. 48 p. 66-9 (Nov 1966).

179 Anon, "Measuring Helps Fight Smoke", Iron Age, V. 198, no. 12, p. 82-83 (Sep 1966).

180 Grimm, W., "Acid Soaked Soot Flakes in Flue Gases - Their Formation and Prevention", Combustion, V. 35, no. 3, p. 38-47 (Sep 1963).

181 Essenhigh, R. H., and Fells, I., "Combustion of Liquid and Solid Aerosols", Faraday Society - Discussion, no. 30, p. 208-21 (1960).

182 Clarke, J. H., "Effective Stack Design in Air Pollution Control", Heating, Piping, and Air Conditioning, V. 40, no.3, p. 125-133 (Mar 1968).

183 Levy, A., and Merryman, E. L., "Sulfur Chemistry and Its Role in Corrosion and Deposits", Journal of Eng. for Power, V. 85, no. 3, p. 229-234 (1963).

184 Finney, C. S., and Spicer, T. S., "The Influence of Particle Size and Volatile Content on the Ignitibility of Pulverized Bituminous Coal", ASME - Paper 62/WA-195, for meeting Nov 25-30, 9 p. (1962).

185 Goldberger, W. M., "Collection of Fly Ash in a Self-Agglomerating Fluidized-Bed Coal Burner", ASME - Paper 67 WA/Fu-3, for meeting Nov 12-17, 16 p. (1967).

186 Pollock, W. A., Tomany, J. P., and Frieling, G., "Sulfur Dioxide and Fly Ash Removal from Coal Burning Power Plant", Air Engineering, V. 9, no. 9, p. 24-28 (Sep 1967).

187 Montgomery, D. J., "Static Electrification of Solids", Solid State Physics, V. 9, Academic Press, New York (1959).

188 Luxl, F. C., and Osochowsky, J. J., "Oxygen Flue Gas Sampling and Analysis on Cyclone-Fired Boilers", Proc. Am. Power Conf., V. 23, p. 481-490 (1961).

189 Walker, A. B., "Emission Characteristics from Industrial Boilers", *Air Engineering*, V. 9, no. 8, p. 17-19 (Aug 1967).

190 Wagoner, C. L., and Duzy, A. F., "Burning Profiles for Solid Fuels", *ASME - Paper 67-WA/Fu-4*, for meeting Nov 12-17, 8 p., (1967).

191 Nacovsky, W., "Determination of Sulfur Oxides in Flue Gas on Stream", *Combustion*, V. 38, no. 7, p. 35-38 (1967).

192 Lisle, E. S., and Sensenbaugh, J. D., "Determination of SO_3 and Acid Dew Point in Flue Gases", *Combustion*, V. 36, no. 7, p. 12-16 (1965).

193 Kolbow, P., and Thieme, R., "Smoke-Density Meter for Supervising the Percentage of Dust Contained in the Flue Gases of Industrial Plants", *Siemens Rev.*, V. 38, no. 8, p. 276-278 (Aug 1965).

194 Kantorovich, B. V., and Delyagin, G. N., "Heat and Mass Transfer in the Process of Fuel Combustion in an Air Stream", *International Journal of Heat & Mass Transfer*, V. 5, p. 11-21 (Jan - Feb 1962).

195 Chopra, S. K., and Narain, S. N., "Measurement of Specific Surface of Fly Ash", *Materials Research & Standards*, V. 4, no. 9, p. 487-490 (Sep 1964).

196 Ray, S. K., and Long, R., "Polycyclic Aromatic Hydrocarbons from Diffusion Flames and Diesel Engine Combustion", *Combustion & Flame*, V. 8, no. 2, p. 139-151 (Jun 1964).

197 Foster, P. J., "Calculation of the Optical Properties of Dispersed Phases", *Combustion & Flame*, V. 7, no. 3, P. 277-282 (Sep 1963).

198 Cullis, C. F., Henson, R. M., and Trimm, D. L., "The Reactivity of Sulphur Dioxide Towards Oxygenated Free Radicals", *Combustion & Flame*, V. 11, no. 2, p. 150-154 (Apr 1967).

199 Erickson, W. D., Williams, G. C., and Hottel, H. C., "Light-Scattering Measurements on Soot in a Benzene-Air Flame", *Combustion & Flame*, V. 8, no. 2, p. 12-132 (1964).

200 Lodge, J. P.,Jr., "Identification of Aerosols", *Advances in Geophysics*, V. 9, p. 97-130 (1962).

201 Soo, S. L., "Pipe Flow of Suspensions", *Applied Scientific Research*, V. 21, p. 68-83 (1969).

202 Middleton, J. B., and Tigges, A. J., "Action of Specific Airborne Contaminants", *Proc., American Power Conference*, V. 24, p. 491-499 (1962).

203 Lambert, W. H., and Schmitz, F. W., "Corrective Measures in Seward Station Equipment and Operation", Proc. American Power Conference, V. 24, p. 499-506 (1962).

204 Altstetter, G. M., and Verrochi, W. A., "Interpretation, Evaluation, and Processing of the Data in the Seward Valley Study", Proc. American Power Conference, V. 24, p. 480-491 (1962).

205 Orning, A. A., Schwartz, C. H., and Smith, J. F., "Minor Products of Combustion in Large Coal-Fired Steam Generators", ASME - Paper 64-WA/Fu-2, for meeting Nov 29 - Dec 4, 12 p. (1964).

206 Barnes, S., Cheng, D. C. H., Yarde, H. R., "The Analysis of Coulter Counter Data", British Journal of Applied Physics, V. 17, no. 11, p. 1501-1506 (1966)

207 Mullen, J. F., "A Method for Determining Combustion Loss, Dust Emission, and Recirculated Refuse for a Solid-Fuel Burning System", ASME - Paper 64-WA/Fu-4, for meeting Nov. 29 - Dec 4, 16 p. (1964).

208 Crandall, W. A., "Development of Standards for Determining Properties of Fine Particulate Matter", ASME - Paper 64-WA/PTC-3, for meeting Nov 29 - Dec 4, 9 p. (1964).

209 Schwoegler, E. J., Putscher, R. E., Combs, H.F., Proudfoot, C. B., and Reilich, H. G., "Methods for Analysis of Residual Fuel Oil", ASME - Paper 63-WA-140, for meeting Nov 17 -22, 8 p. (1963).

210 Sexton, R. W., "Stack Sampling of Chemical Mists and Vapors", American Indust. Hygiene Assoc. Journal, V. 25, no. 4 p. 346-353 (1964).

211 Marsh, R. C., "A Comparison of Dust Count Data Obtained from Different Measuring Methods", ASTM - Special Tech. Publ. 342, p. 24-28 (1967).

212 Minnick, L. J., "Fundamental Characteristics of Pulverized Coal Fly Ashes", Am. Soc. of Testing Materials Proc., V. 59, p. 1155-1177 (1959).

213 Siegmund, C. W., and Manny, E. H., "Changing Patterns of Fuel Oil--Influence of Sulfur Regulations", Combustion, V. 40, no. 7, p. 36-41 (Jan 1969).

214 Chakraborty, B. B., and Long, R., "The Formation of Soot and Polycyclic Aromatic Hydrocarbons in Diffusion Flames - 1, 2,", Combustion & Flame, V. 12, no. 3, p. 226-42 (Jun 1968).

215 Fenimore, C. P., and Jones, G. W., "Comparative Yields of Soot from Premixed Hydrocarbon Flames", Combustion & Flame, V. 12, no. 3, p. 196-200 (Jun 1968).

216 Scaringelli, F. P., and Frey, S. A., "Evaluation of Teflon Permeation Tube for Use with Sulfur Dioxide", American Industrial Hygiene Assoc. Journal, V. 28, no. 3, p. 260-266 (1967).

217 Cuffe, S. T., "Air Pollutants from Power Plants. Techniques for Evaluating Air Pollutants", Arch. Environmental Health, V. 6, p. 422-427 (Mar 1963).

218 Brandon, J. H., "Can A Fuel Treatment Program Control Stack Emissions?", Combustion, p. 20-24 (Oct 1969).

219 Slack, A. V., and Falkenberry, H. L., "Sulfur-Dioxide Removal from Power Plant Stack Gas by Limestone Injection", Combustion, p. 15-21 (Dec 1969).

220 Jung, R., "Gefassonde zum Messen des Staubgehaltes in stromenden Gasen", Chemie-Ing.-Tech., V. 41, p. 620-625 (1969).

221 Collis, R. T. H., "Lidar for Routine Meteorological Observations", American Meteorological Society Bul., V. 50, no. 9, p. 688-694 (Sep 1969).

222 Frazier, J. H., "Coal Fired Boiler Stack Emission Control", National Engineer, p. 8 - 11 (Aug 1969).

223 Tassicker, O.J., "Particle Measuring Apparatus Including Constant Temperature Electrostatic Precipitator and Resistance Measuring Chambers", U.S. Patent No. 3,473,118 (Oct 1969).

224 Vonnegut, B., "Means for Measuring Individual Aerosol Particles", U.S. Patent No. 2,702,471 (Feb 1955).

225 Duwel, L., "Latest State of Development of Control Instruments for the Continuous Monitoring of Dust Emissions", Staub-Reinhalt der Luft (Engl. Trans.), V. 28, no. 3, p.42-53 (Mar 1968).

226 Coenen, W., "A New Principle of Recorded Dust Measurement and Its Technical Application in a Battery-Powered Instrument", Staub-Reinhalt der Luft (Engl. Trans.), V. 27, no. 12, p. 32-40 (Dec 1967).

227 Aurand, K., "Recording Counter for the Continuous Determination of the Concentration of Pulverulent Air Pollutants", Staub-Reinhalt der Luft (Engl. Trans.), V. 27, no. 10, p. 21-24 (Oct 1967).

228 Zebel, G., "The Use of Electrical and Magnetic Forces to Separate and Classify Aerosol Particles", Staub-Reinhalt der Luft (Engl. Trans.), V. 28, no. 7, p. 1-4 (Jul 1968).

229 Avy, A. P., Benarie, M., and Hartogensis, F., "Comparision of Dust Samplers and Sampling Methods", Staub-Reinhalt der Luft (Engl. Trans.), V. 27, no. 11, p. 1-16 (Nov 1967).

230 Nester, K., "Statistical Frequency Data on Maximum Concentrations of Stack Emissions as Based on Synoptic Weather Observations", Staub-Reinhalt der Luft (Engl. Trans.),(Volume & Date Unknown).

231 Odelycke, P., "Comparative Investigations of Various Dust Measuring Instruments", Staub-Reinhalt der Luft (Engl. Trans.), (Volume & Date Unknown).

232 Polydorova, M., "Determining the Concentration of Ultrafine Aerosol Particles by Means of the Thermal Precipitator", Staub-Reinhalt der Luft (Engl. Trans.), V. 27, no. 10, p. 24-28 (Oct 1967).

233 Simecek, J., "Measurement Asbestos Dust", Staub-Reinhalt der Luft (Engl. Trans.), V. 27, no. 11, p. 20-33 (Nov 1967).

234 Schonauer, G., "The Electron-Microscopic Determination of Droplet-Size Distribution in Oilmists Using the Flattening Factor", Staub-Reinhalt der Luft (Engl. Trans.), V. 27, no. 11, p. 23-27 (Nov 1967).

235 Lahmann, E., "Evaluation of Continuous Air-Quality Measurements by Point Recording", Stuab-Reinhalt der Luft, (Engl. Trans.), V. 27, no. 11, p. 27-29 (Nov 1967).

236 Winkel, A., "The Measurement and Assessment of Dust Concentrations at the Working Place with Special Consideration of the Use of Different Dust Samples", Staub-Reinhalt der Luft (Engls. Trans.), V. 28, no. 1, p. 1-8 (Jan 1968).

237 Anon, Determining Dust Concentration in a Gas Stream, American Society of Mechanical Engineers, PTC 27-1957, 25 p. (1957).

238 Anon, Dust Separating Apparatus, American Society of Mechanical Engineers, PTC 21-1941, 29 p. (1941).

239 Anon, Determining the Properties of Fine Particulate Matter, American Society of Mechanical Engineers, PTC-28-1965, 40 p. (1965).

240 Walter, E., "Kontinuierlich Arbeitende Uberwachungsgerate fur dent Staubgehalt ruhender Luft und Stromender Gase", Staub-Reinhalt der Luft, V. 22, no. 4, p. 162-165 (Apr 1962).

241 Konig, W., and Rock, H., "Untersuchungen am elektrostatischen Staubgehaltsmessgerate Konitest", Staub-Reinhalt der Luft, V. 21, no. 8, p. 355-356 (Aug 1961).

242 Hasenclever, D., and Siegmann, H., "Neue Methode der Staubmessung mittels Kleinionenanlagerung", Staub-Reinhalt der Luft, V. 20, no. 7, p. 212-218 (Jul 1960).

243 Gast, T., "Staubmessgerate mit massenproportionaler Anzeige oder Registrierung", Staub-Reinhalt der Luft, V. 20, no. 8, p. 266-272 (Aug 1960).

244 Olin, J. G., and Sem, G. J., "Piezoelectric Aerosol Mass Concentration Monitor", paper presented at Symp. on Advances in Instrumentation for Air Pollution control, Cincinnati, Ohio, May 26-28, 1969.

245 Coenen, W., "Registrierende Staubmessung nach der Methode der Kleinionenanlagerung", Staub-Reinhalt der Luft, V. 24, no. 9, p. 350-353 (Sep 1964).

246 Donnelly, J. W., "Development and Evaluation of Boiler Smoke Density Optimizer", Naval Ship Engineering Center, Philadelphia, Pa. Clearinghouse No. AD 662 415 (Nov 1967).

247 Olaf, J., and Somolyai, J., "Two-Channel Fractiometer for the Particle Size Analysis of Suspended Dust", Staub-Reinhalt der Luft, V. 28, no. 9 (Sep 1968).

248 Horn, W., "Process for Continuous Gravimetric Determination of the Concentration of Dustlike Emissions", Staub-Reinhalt der Luft (Engl. Trans.), V. 28, no. 9, p. 20-25 (Sep 1968).

249 Hofmann, K. P., and Mohnen, V., "The Operation of the Acoustic Particle Counter", Staub-Reinhalt der Luft (Engl. Trans.), V. 28, no. 9, p. 15-20 (Sep 1968).

250 Langer, G., "The Langer Acoustic Particle Counter", Staub-Reinhalt der Luft (Engl. Trans.), V. 28, no. 9, p. 13-14 (Sep 1968).

251 Barrick, D. E., and Peake, W.H., "Scattering from Surfaces with Different Roughness Scales: Analysis and Interpretation", Battelle Mem. Inst., Columbus, Ohio, Clearinghouse No. AD 662 751 (Nov 1967).

252 Rogallo, V. L., and Neuman, F., "A Wide-Range Piezoelectric Momentum Transducer for Measuring Micrometeoroid Impacts", Ames Research Center, Moffett Field, Calif, Clearinghouse No. NASA TN D-2938 (Jul 1965).

253 Zinky, W. R., "Hologram Camera and Reconstruction System for Assessment of Explosively Generated Aerosols", Technical Operations Research, Burlington, Mass, Clearinghouse No. AD 474 534 (Oct 1965).

254 Chaikivsky, M., and Siegmund, C. W., "Low-Excess-Air Combustion of Heavy Fuel-High-Temperature Deposits and Corrosion", Journal of Eng. Power, V. 87, no. 4, p. 279-288 (1965).

255 Franklin, J. L., "Mechanisms and Kinetics of Hydrocarbon Combustion", Annu. Rev. Phys. Chem., V. 18, p. 261-282 (1967).

256 Boothroyd, R. G., "An Anemometric Isokinetic Sampling Probe for Aerosols", Journal of Scientific Instruments, V. 44, no. 4, p. 249-253 (1967).

257 Narjes, L., "Dust Sampler Equipment for Quasi-Isokinetic Sampling by Means of Novel Zero-Pressure Probes", Chem. Age of India, V. 19, no. 8, p. 595-603 (Aug 1968).

258 Mitchell, E. R., and Lee, G. K., "Agglomeration of Superfine Fly Ash in High-Velocity Gas Streams", Canadian Inst. Min. & Met. Trans. Min. Soc. of Nova Scotia, V. 65, p. 380-384 (1962).

259 Wilson, H. N., and Duff, G.M.S., "Industrial Gas Analysis", Analyst, V. 92, no. 1101, p. 723-758 (1967).

260 Anon, "Direct Indication of Particle Size in Fluidized Beds", Argonne National Laboratory, Argonne, Illinois, NASA Tech. Brief 69-10083 (Mar 1969).

261 Lee, R. E., Jr., and Patterson, R. K., "Size Determination of Atmospheric Phosphate, Nitrate, Chloride, and Ammonium Particulate in Several Urban Areas", Atmospheric Environment, V. 3, no. 3, p. 249-255 (May 1969).

262 Yankovskii, S.S., and Fuks, N. A., "Particle Size Analysis of Industrial Aerosols According to Their Stokes Diameters", Industrial Laboratory, V. 32, no. 7, p. 996-1000 (Jul 1966).

263 Achinger, W. C., and Shigehara, R. T., "Guide for Selected Sampling Methods for Different Source Conditions", APCA Journal, V. 18, no. 9, p. 605-609 (Sep 1968).

264 Takahashi, K., and Kasahara, M., "A Theoretical Study of the Equilibrium Particle Size Distribution of Aerosols", Atmospheric Environment, V. 2, no. 5, p. 441-453 (Sep 1968).

265 Bostrom, C.E., and Brossett, C., "Methods for Simultaneous Determination of H_2S and SO_2 in Flue Gases", Atmospheric Environment, V. 3, no. 4, p. 407-416 (Jul 1969).

266 Wilson, L. G., and Cavanagh, P., "A Stero-Ultra-Microscope for Studying Sub-Micron Aerosols", Atmospheric Environment, V. 3, no. 1, p. 47-53 (Jan 1969).

267 Tabata, N., and Mori, M., "Determination of Fine Particle Size by Laser Beam", Electrical Eng. in Japan, V. 88, no. 6, p. 74-81 (Jun 1968).

268 Tipping, F., "Oxygen Analysis in Chemical Plant", Chem. & Process Eng., V. 40, no. 10, p. 82-84, 89 (Oct 1968).

269 Hanst, P. L., and Morreal, J. A., "Detection and Measurement of Air Pollutants by Absorptions of Infrared Radiation", APCA Journal, V. 18, no. 11, p. 754-759 (Nov 1968).

270 Seger, B., "Application of Holography for Particle Size Analysis in Aerosol Clouds", Soap & Chemical Specialties, p.105 (Oct 1969).

271 Harris, F. S., Jr., Morse, F.L., Jr., and Taliaferro, N. G., "Laser Photometer for Particle-Size Measurements", Optical Society of America, 1969 Annual Meeting Proc., (1969).

272 Stober, W., "Design and Performance of a Size-Separating Aerosol Centrifuge Faciliating Particle Size Spectrometry in the Sub Micron Range", University of Rochester, New York, Clearinghouse No. Conf-670704-4 (1967).

273 Anon, "The Tall Stack for Air Pollution Control on Large Fossil-Fueled Power Plants, a collection of recent papers with an introduction by Philip Sporn, American Electric Power Company, New York, N.Y. (1967).

274 Anon, "Dust Emission Control in Calcium Carbide Production" Translated from German, Clearinghouse No. TT 68 50469/2 (Dec 1965).

275 Anon, "Emission Control Blast Furnace Operation Ore Sintering Plants (Induced-Draft Pan and Moving-Grate Installations)", Translated from German, Clearinghouse No. TT 68 50469/1 (Feb 1963).

276 Nelson, M. B., "Fabrication of Particle Counters for Clean Rooms", ITT Research Institute, Chicago, Ill., NASA Tech. Brief 67-10076. (Jul 1966).

277 Park, J. C., Keagy, D. M., and Stalker, W. W., "Developments in the Use of the A.I.S.I. Automatic Smoke Sampler", Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, 10 p. plus fig.

278 Sunavala, P. D., "Computations on Incomplete Combustion", Journal of Mines, Metals, & Fuels, V. 15, no. 8, p. 242-244 (1967).

279 Langer, G., Pierrard, J., and Yamate, G., "Further Development of an Electrostatic Classifier for Submicron Airborne Particles", Int. J. Air Wat. Poll., V. 8, p. 167-176 (1964).

280 Barrett, E.W., "Lidar Measurements of Particulate Concentration Profiles", Paper 67-128 presented at 60th Annual Meeting of Air Pollution Control Assoc., Cleveland, Ohio, June 11-16, 1967.

281 Boubel, R. W., and Wise, K. R., "An Emission Sampling Probe Installed, Operated, and Retrieved from Ground Level", Paper 67-118 presented at 60th Annual Meeting of Air Pollution Control Assoc., Cleveland, Ohio, June 11-16, 1967.

282 Shephard, R. J., Carey, G. C. R., and Phair, J.J., "Critical Evaluation of a Filter-Strip Smoke Sampler Used In Domestic Premises", A.M.A. Archives of Industrial Health, V. 17, p. 236-252 (Mar 1958).

283 Pueschel, R. F., and Charlson, R. J., "Aerosol Characteristics and Light Extinction", paper presented at 47th Annual Meeting of Pacific Div., American Assoc. for the Advancement of Science, Seattle, (Jun 1966).

284 Coenen, W., "Staubmonitor zur betrieblichen Staububerwachung", Staub-Reinhalt der Luft, V. 23, no. 2, p. 119-123 (Feb 1963).

285 Doyle, A. W., and Weiderhorn, N.M., "The Use of a Light-Scattering Photometer in Air Pollution Studies", paper presented at 3rd Annual Meeting, New England Section, Air Pollution Control Assoc.,May 14, 1959.

286 Northend, C. A., Honey, R. C., and Evans, W. E., "Laser Radar (Lidar) for Meteorological Observations", Review of Scientific Instruments, V. 37, no. 4, p. 393-400 (1966).

287 Anon, "Reference Manual for the Southern Research Institute Particle Size Analyzer", Southern Research Institute, Birmingham, Alabama (Oct 1959).

288 Fisher, M. A., Katz, S., Lieberman, A., and Alexander, N.E., "The Aerosoloscope; An Instrument for the Automatic Counting and Sizing of Aerosol Particles", Proc. 3rd National Air Pollution Symposium, Pasadena, Calif., p. 112-119 (Apr 18-20 1955).

289 Frostling, H., and Lindgren, P. H., "A Flame Ionization Instrument for the Detection of Organic Aerosols in Air", Journal of Gas Chromatography, p. 243-245 (Jul 1966).

290 Goetz, A., and Kallai, T., "Determination of Size and Mass Distribution of Aerosols", Symposium on Air-Pollution Measurement Methods, Special Tech. Pub. No. 352, ASTM, p. 40-55 (1964).

291 Haagen-Smit, A. J., Taylor, V. D., and Brunelle, M. F., "Spectroscopic Analysis of Industrial Emissions for Nitric Oxide, Nitrogen Dioxide, and Sulfur Dioxide", Industrial Engineering & Chemistry, V. 51, p. 772 (1959).

292 Kerker, M., Farone, W. A., and Jacobsen, R. T., "Color Effects in the Scattering of White Light by Micron and Submicron Spheres", Optical Society of America Journal, V. 56, no. 9, p. 1248-55 (1966).

293 Langer, G., and Radnik, J. L., "Development and Preliminary Testing of a Device for Electrostatic Classification of Submicron Airborne Particles", Journal of Applied Physics, V. 32, p. 955-957 (1961).

294 Mitchell, R. I., and Pilcher, J. M., "Cascade Impactor for Measuring Aerosol Particle Size", Industrial and Engineering Chemistry, V. 51, p. 1039-1042 (1959).

295 Orr, C., and Martin, R. A., "Thermal Precipitator for Continuous Aerosol Sampling", Review of Scientific Instruments, V. 29, p. 129-130 (1958).

296 Schadt, C., and Cadle, R. D., "Critical Comparison of Collection Efficiences of Commonly Used Aerosol Sampling Devices", Analytical Chemistry, V. 29, p. 864-868 (1957).

297 Shapiro, A. H., and Erickson, A. J., "On the Changing Size Spectrum of Particle Clouds Undergoing Evaporation, Combustion, or Acceleration", American Society of Mechanical Engineers Trans., V. 79, p. 775-788 (1957).

298 Smith, A. C., "The Determination of Trace Elements in Pulverized-Fuel Ash", Journal of Applied Chemistry, V. 8, p. 636-645 (1958).

299 Yoshikawa, H. H., Swartz, G. A., MacWaters, J. T., and Fite, W. L., "Electrostatic Particle Size Analyzer", Review of Scientific Instruments, V. 27, p. 359-362 (1956).

300 Austin, H. C., and Chadwick, W. L., "Control of Air Pollution from Oil-Burning Power Plants", Mechanical Engineering, V. 82, p. 63-66 (1960).

301 Austin, H. C., and Chadwick, W. L., "Control of Air Pollution from Oil-Burning Power Plants", Mechanical Engineering, V. 82, no. 8, p. 92-94 (1960).

302 Slone, T. J., Lagarias, J. S., and Schlaffer, G. C., "Stack Effluent Monitoring for Power Stations", Reprint No. 285, American Inst. Co., Inc., Silver Spring, Md.

303 Hemeon, W. C. L., Sensenbaugh, J. D., and Haines, G.F., Jr., "Measurement of Air Pollution", Instruments, V. 26, p. 566-570 (Apr 1953).

304 Guinier, A., "Determination of the Size of Submicroscopic Particles by X-Rays", U. S. Bureau of Mines, Information Circular 7391 (Dec 1946).

305 Schumann, C. E., and Gruber, C. W., "A Recommended Method for Soiling Index Surveys by Automatic Filter Paper Sampler", Paper 60-37 presented at 53rd Annual Meeting of Air Pollution Control Assoc., Cincinnati, Ohio (May 22-26, 1960).

306 Horn, J. E., Collins, R. H., and Bird, A. N., Jr., "Sampling of Chemical Agents for Concentration and Particle Size", Report No. 20, Southern Research Institute, Birmingham, Alabama, Clearinghouse No. AD 459 583 (Mar 1965).

307 Kay, K., "Analytical Methods Used in Air Pollution Study", Industrial and Engineering Chemistry, V. 44, p. 1383-1388 (1952).

308 Hemeon, W. C. L., "Instruments for Air Pollution Measurement, Meteorological Monographs,V. 1, no. 4 (Nov 1951).

309 Katz, M., and Clayton, G. D., "Instrumentation and Analytical Techniques for the Continuous Determination of Air Contaminants", American Society of Testing Materials Proc., V. 53, p. 1137-1157 (1953).

310 Silverman, L., "Sampling and Analyzing Air for Contaminants", Air Conditioning, Heating, and Ventilating, V. 52, no. 8, p. 88-100 (1955).

311 Huge, E. C., and Poitter, E. C., "The Use of Additives for the Prevention of Low-Temperature Corrosion in Oil-Fired Steam-Generating Units", American Society of Mechanical Engineers Trans., V. 77, p. 267-278 (1955).

312 Devitofrancesco, G., and Liberti, A., "Determining the Dust Concentration by Surface Measurements", Staub Reinhalt der Luft (Engl. Trans.), (Volume & Date Unknown).

313 Katz, Jr., and Verrochi, W. A., "A Filter Test Method for Rapid Weight Distribution of Dust in Gas Streams to Evaluate Dust Collectors", APCA Journal, V. 18, no. 6, p. 401-402 (Jun 1968).

314 Dobbins, R. A., and Temkin, S., "Measurements of Particulate Acoustic Attenuation", AIAA Journal, V. 2, no. 6, p. 1106-1111 (Jun 1964).

315 Keily, D. P., "Recent Progress in the Measurement of Liquid Drop-Size Distribution", Dept. of Meteorology, Mass. Inst. Tech., published in Air, Space, and Instruments.

316 Ward, J. H., "Holographic Particle Sizing", Technical Operations, Inc., Burlington, Mass., 17 p.

317 Dunning, J. W., Jr., and Angus, J. C., "Particle-Size Measurement by Doppler-Shifted Laser Light, a Test of the Stokes-Einstein Relation", Case Institute of Technology, Cleveland, Ohio (1967).

318 Thompson, B. J., "Applications of Fraunhofer Holograms", Technical Operations, Inc., Mountain View, Calif., 9 p.

319 Lennert, A. E., Brayton, D. B., Goethert, W. H., and Smith, F. H., "Laser Applications for Flow Field Diagnostics", presented at 2nd National Laser Industry Ass'n. meeting, Los Angeles, Calif., Oct. 20-22, 1969. (Pub. Electro-Technology, Feb 1970).

320 Gronhovd, G. H., Harak, A. E., and Tufte, P. H., "Ash Fouling and Air Pollution Using A Pilot Plant Test Furnace", presented at 1969 Lignite Symposium, Grand Forks, N.D. (May 1-2 1969).

321 Gronhovd, G. H., Beckering, W., and Tufte, P. H., "Study of Factors Affecting Ash Deposition from Lignite and Other Coals", ASME Paper 69-WA/CD-1, for meeting (Nov 16-20 1969).

322 Kube, W., and Elder, J. L.,"Technology and Use of Lignite", proc., Bureau of Mines-U. of No. Dakota Symp., Grand Forks, N.D., Apr 27-28,1967, U.S. Bureau of Mines Information Circular 8376 (May 1968).

323 Elder, J. L., and Kube, W. R., "Technology and Use of Lignite", Proc., U.S. Bureau of Mines-U. of N. D. Symp., Bismarck, N.D., Apr 29-30, 1965. U.S. Bureau of Mines Information Circular 8304 (1966).

324 Matty, R. E., and Diehl, E. K., "Measuring Flue-Gas Sulfur Dioxide and Sulfur Trioxide", Power, V. 101, no. 11, p. 94-97 (1957).

325 Rich, T. A., "Characteristics of Airborne Particles", Journal of Eng. for Power, V. 81, p. 7-12 (1959).

326 Brief, R. S., and Drinker, P. A., "Collection of Integrated Samples of Gaseous Effluents", A. M. A., Archives Ind. Health, V. 16, p. 654 (1958).

327 Robinson, M., "A Miniature Electrostatic Precipitator from Sampling Aerosols", Analytical Chemistry, V. 33, p. 109-113 (1961).

328 Stephens, J. F., "A Practical Stack Sampling Procedure", American Ind. Hygiene Assoc. Journal, V. 22, p. 377-384 (1961).

329 Silverman, L., "An Automatic Monitoring System for Stack Particulates", American Industrial Hyg. Assoc. Journal, V. 25, p. 529-544 (1964).

330 Monkman, J. L., Moore, G. E., and Katz,M., "Analysis of Polycyclic Hydro-Carbons in Particulate Pollutants", American Industrial Hyg. Assoc. Journal, V. 23, p. 487-495 (1962).

331 Stevenson, H. J. R., Sanderson, D. E., and Altshuller, A. P., "Formation of Photochemical Aerosols", Int. J. Air Wat. Poll., V. 9, no. 6, p. 367-375 (1965).

332 Harris, W. B., "Spread of Particulate Contamination from Stacks", A.M.A. Arch. Ind. Health, V. 15, p. 274-283 (1957).

333 Smith, W. S., and Gruber, C. W., "Atmospheric Emissions from Coal Combustion, An Inventory Guide", Public Health Service, Publication No. 999-AP-24 (Apr 1966).

334 Anon., Power Plant Data (1970).

335 Dresia, H., Fischotter, P., and Felden, G., "Kontinuierliches Messen des Staubegehaltes in Luft und Abgasen mit Betastrahlen", VDI-Z, V. 106, no. 24, p. 1191-1195 (Aug 1964).

336 Fawcett, H. H., and Gardner, G., "A Small Particle Detector", Industrial and Engineering Chemistry, p. 87A - 88A (1958).

337 Simecek, J., "Comparative Investigation of Methods for Particle Size Determination", Staub Reinhalt der Luft (Engl. Trans.), V. 27, no. 6, p. 33-37 (Jun 1967).

338 Luckert, J., "Aerosol Convention Mainz - 26-28 Oct 1966", Staub Reinhalt der Luft (Engl. Trans.), V. 27, no. 2, p. 59-62 (Feb 1967).

339 Price, J. G. W., Fenimore, D. C., Simmonds, P. G., and Zlatkis, A., "Design and Operation of a Photoionization Detector for Gas Chromatography", Analytical Chemistry, V. 40, no. 3, p. 541-547 (Mar 1968).

340 Setzer, D. E., "Comparison of Measured and Predicted Aerosol Scattering Functions", Applied Optics, V. 8, no. 3, p. 905=911 (May 1969).

341 Lapple, C. E., "Particle Size Analysis and Analyzers", Chemical Engineering, V. 75, no. 11, p. 149-156 (May 1968).

342 Anon, "How to Keep Watch on What Goes Up the Stack", Chemical Week, V. 105, no. 5, p. 31-32 (Aug 1969).

343 Ahlquist, N. C., and Charlson, R. J., "Measurement of the Vertical and Horizontal Profile of Aerosol Concentration in Urban Air with the Integrating Nephelometer", Environmental Science & Technology, V. 2, no. 5, p. 363-366 (May 1968).

344 Chakraborty, B. B., and Long, R., "Gas Chromatographic Analysis of Polycyclic Aromatic Hydrocarbons in Soot Sample", Environmental Science & Technology, V. 1., no. 10, p. 828-834 (Oct 1967).

345 Ludwig, F. L., "Behavior of Numerical Analog to a Cascade Impactor", Environmental Science & Technology, V. 2, no. 7, p. 547-550 (Jul 1968).

346 Brown, P. M., "A Modification of the Bausch and Lomb Aerosol Dust Counting System to Automatically Measure Aerosol Size Distributions, Environmental Science & Technology, V. 3, no. 8, p. 768-769 (Aug 1969).

347 Wartburg, A. F., Pate, J. B., and Lodge, J. P., Jr., "An Improved Gas Sampler for Air Pollutant Analysis", Environmental Science & Technology, V. 3, no. 8, p. 767-768 (Aug 1969).

348 Stober, W., Berner, A., and Blaschke, R., "The Aerodyanmic Diameter of Aggregates of Uniform Spheres", Journal of Colloid & Interface Science, V. 29, p. 710-719 (1969).

349 Langer, G., "An Acoustic Particle Counter - Preliminary Results", Journal of Colloid Science, V. 20, p. 602-609 (Aug 1965).

350 Whitby, K. T., Liu, B.Y.H., and Peterson, C. M., "Charging and Decay of Monodispersed Aerosols in the Presence of Unipolar Ion Sources", Journal of Colloid Science, V. 20, p. 585-601 (Aug 1965).

351 Ludwig, F. L., and Robinson, E., "Size Distribution of Sulfur-Containing Compounds in Urban Aerosols", Journal of Colloid Science, V. 20, p. 571-584 (Aug 1965).

352 Zvonow, V. A., Stewart, H. E., and Starkman, E. S., "Hydraulically Actuated Combustion Gas Sampling Valve",Review of Scientific Instruments, V. 39, no. 12, p. 1820-1824 (Dec 1968).

353 Nader, J. S., "Instrumentation in the Study of Air Pollution", ISA - Nat. Symposium on Instrumental Methods of Analysis, 8th - Proc., p. 11-33 (1962).

354 Goetz, A., and Kallai, T., "Instrumentation for Determining Size- and Mass-Distribution of Submicron Aerosols", APCA Journal, V. 12, no. 10, p. 479-486 (Oct 1962).

355 Boubel, R. W., and Ripperton, L. A., "Benzo(a) Pyre Procution During Controlled Combustion", APCA Journal, V. 13, no. 11, p. 553-557 (1962).

356 "Measurement of Stack Gas Velocity and Methods of Sampling Stack Gases and Their Particulates - Literature Search", Engineering Societies Library, Coordinating Committee on Air Pollution, New York, Search No. 6216, 20 p (1962).

357 Weintrabb, M., Goldberg, S. A., and Orning, A. A., "A Study of Sulfur Reactions in Furnace Deposits", Journal of Eng. Power, V. 83, p. 444-450 (Oct 1961).

358 Quack, R., "Dust and Gaseous Emissions from Thermal Power Stations", Trans. World Power Conf., Tokyo, V. 3, Sec. 2A (1) for meeting Oct 16 - 20, 1966, Paper 60, p. 1277-1296.

359 Hogstrom, U., "A Statistical Approach to the Air Pollution Problem of Chimney Emission", Atmospheric Environment", V. 2, no. 3, p. 251-271 (May 1968).

360 Dorsey, J. A., and Kemnitz, D. A., "A Source Sampling Technique for Particulate and Gaseous Fluorides", APCA Journal, V. 18, no. 1, p. 12-14 (Jan 1968).

361 Twomey, S., Severynse, G. T., "Measurements of Size Distributions of Natural Aerosols", Journal of Atmospheric Sciences, V. 20, no. 5, p. 393-396 (Sep 1963).

362 Welch, E. C., "Design of an Optical System for Counting and Sizing Airborne Particles", ISA - Nat. Symposium on Instrumental Methods of Analysis, 8th - Proc., p. 173-178 (1962).

363 Laxton, J. W., and Jackson, P. J., "Automatic Monitor for Recording Sulphur Trioxide in Flue Gas", Inst. Fuel Journal, V. 37, no. 276, p. 12-17 (Jan 1964).

364 Rendle, L. K., "Measurement of the Flue Gas Solids Burden from Oil-Fired Installations Using Silica Wool Filter", Inst. Fuel Journal, V. 37, no. 276, p. 25-30 (Jan 1964).

365 George, R. E., and Chass, R. L., "Control of Contaminant Emissions from Fossil Fuel-Fired Boilers", Am. Chem. Soc. Div. Fuel Chemistry, V. 10, no. 1, p. 31-56, papers for meeting March 22-31, 1966.

366 Bodurtha, F. T., Jr., "Control of Power Plant Stack Emissions for Clear Air", Am. Power Conf. Proc., V. 27, p. 399-411 (Apr 1965).

367 Pesterfield, C. H., "Literature and Research Survey to Determine Necessity and Feasibility of Air Pollution Research Project on Combustion of Commercially Available Fuel Oils", APCA Journal, V. 14, no. 6, p. 203-207 (Jun 1964).

368 Hangebrauck, R. P., Von Lehnden, D.J., and Meeker, J. E., "Emissions of Polynuclear Hydrocarbons and other Pollutants from Heat-Generation and Incineration Processes", APCA Journal, V. 14, no. 7, p. 267-278 (Jul 1964).

369 Goetz, A., "Methods for Measuring Particle Composition in Photoactivated Aerosols", APCA Journal, V. 14, no. 6, p. 213-219 (Jun 1964).

370 Zinky, W. R. "A New Tool for Air Pollution Control, the Aerosol Particle Counter", APCA Journal, V. 12, no. 12, p. 578-583 (Dec 1962).

371 Conner, W. D., "An Inertial-Type Particle Separator for Collecting Large Samples", APCA Journal, V. 16, no. 1, p. 35-8 (Jan 1966).

372 Dixon, W. S., "Selecting Proper Flue-Gas Probes", ISA Journal, V. 8, no. 12, p. 42-45 (Dec 1961).

373 Goksoyr, H., and Ross, K., "Determination of Sulphur Trioxide in Flue Gases", Journal Inst. of Fuel, V. 35, no. 255, p. 177-179 (Apr 1962).

374 Mueller, P. K., and Givens, R. G., "Dynamic Calibration and Data Interpretation of a Light-Scattering Instrument", APCA Journal, V. 11, no. 12, p. 576-580, 584 (Dec 1961).

375 Boubl, R. W., and Ripperton, L. A., "Oxides of Nitrogen and Unburned Hydrocarbons Produced During Controlled Combustion", APCA Journal, V. 15. no. 6, p. 270-273 (Jun 1965).

376 Graziano, E., "White-Rooms and Sub-Micron Aerosol Particle Control", Lockheed Missiles and Space Co., Sunnyvale, Calif., Clearinghouse no. AD 271 692 (Oct 1961).

377 Anon, "Bibliography on Methods of Sampling Airborne Particles", Technical Library, Camp Detrick, Frederick, Md., Clearinghouse No. AD 294 879 (Aug 1956).

378 Anon, "Supplement to Bibliography on Methods of Sampling Airborne Particles", Technical Library, Camp Detrick, Frederick, Md., Clearinghouse No. AD 294 880 (Nov 1956).

379 Collis, R. T. H., "Lidar Observations of Atmospheric Motion in Forest Valleys", Bull. American Meteorological Society, V. 49, no. 9, p. 918-922 (Sep 1968).

380 Angerhofer, A. W., "Cryogenic Instrumentation, II - Sensing Flow and Composition", Control Engineering, V. 12, no. 11, p. 77-84 (Nov 1965).

381 Angerhofer, A. W., "Cryogenic Instrumentation, I - Sensing Flow and Composition", Control Engineering, V. 12, no. 10, p. 67-73 (Oct 1965).

382 Chakraborty, B. B., and Long, R., "The Formation of Soot and Polycyclic Aromatic Hydrocarbons in Diffusion Flames, Part Three", Combustion & Flame, V. 12, no. 5, p. 469-476 (Oct 1968).

383 Anon, "Air Pollution Control: An Instrumentation Challenge", Control Engineering, V. 13, no. 6, p. 18-19 (Jun 1966).

384 Crecelius, L. P., "Combustion of Low-Grade Coals", Combustion, V. 25, no. 6, p. 63-65 (1953).

385 Karney, J. L., Lea, D. A., and Knudsen, C. A., "Laser Radar Returns from the Lower Troposphere Compared with Vertical Ozone Distributions", Pacific Missile Range, Point Mugu, Calif., Clearinghouse No. AD 649 700 (Mar 1967).

386 Sodha, M. S., and Kaw, P. K., "Field Emission from Negatively Charged Solid Particles", British Journal of Applied Physics, (J. Phys. D), Ser. 2, V. 1, p. 1303-1307 (Oct 1968).

387 Seiler, E., "Comparison of Source Sampling Techniques", Air Conditioning, Heating, & Ventilating, V. 65, no. 3, p. 17-21 (Mar 1968).

388 Mullen, H., "Solids Emission Problems", ASHRAE Journal, V. 8, no. 6, p. 35-37 (Jul 1966).

389 Gandin, L. S., and Soloveichik, R. E., "On the Propogation of Smoke from Factory Stacks", Translated from Russian, Clearinghouse No. AD 660 973 (Jan 1961).

390 Lockhart, L. B., Jr., Patterson, R. L., Jr., and Saunders, A. W., Jr., "Filter Pack Technique for Classifying Radioactive Aerosols by Particle Size, Part 5, Final Report, Naval Research Lab., Washington, D. C., Clearinghouse No. AD 649 728 (Mar 1967).

391 MacEwen, J. D., "Contaminant Generation Methods and Techniques", in: Proc. Conference on Atmospheric Contamination in Confined Spaces, March 30 - April 1, 1965, Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, Clearinghouse No. AD 629 622 (1965).

392 Lundgren, D., and Long, W., "Particle Size-Distribution Data Using an Inertial Classification-Light Scattering Device", APCA Journal, V. 17, p. 594 (1967).

393 Lundgren, D., and Cooper, D., "Effects of Humidity on Light-Scattering Methods of Measuring Particle Concentrations", APCA Journal, V. 17, p. 592-593 (1967).

394 Kerker, M., and Matijevic, E., "Preparation of Submicron Aerosols of Narrow Size Distribution and Their Analysis of Light Scattering", APCA Journal, V. 18, p. 665-667 (1968).

395 Bienstock, D., Amsler, R. L., and Bauer, E. R., Jr., "Formation of Oxides of Nitrogen in Pulverized Coal Combustion", APCA Journal, V. 16, p. 442-445 (1966).

396 Gruber, C. W., and Schumann, C. E., "Soiling Potential - A New Method for Measuring Smoke Emission", APCA Journal, V. 16, p. 272-275 (1966).

397 Anderson, F. G., and Tomb, T. F., and Jacobsen, M., "Analyzing Midget Impinger Dust Samples with an Electronic Counter", U. S. Bureau of Mines, Report of Investigations No. 7105 (Apr 1968).

398 Hovey, H. H., Risman, A., and Cunnan, J. F., "Development of Air Contaminant Emission Tables for Nonprocess Emissions", APCA Journal, V. 16, no. 7, p. 362-366 (1966).

399 Scaringelli, F. P., Boone, R. E., and Jutze, G. A., "Dynamic Calibration of an Acid Aerosol Analyzer", APCA Journal, V. 16, no. 6, p. 310-313 (1966).

400 Lehmden, D. J., Hangebrauck, R. P., and Meeker, J. E., "Polynuclear Hydrocarbon Emissions from Selected Industrial Processes", APCA Journal, V. 15, no. 7, p. 306-312 (1965).

401 Shafer, H. E., Jr., and Holland, C. T., "Western States Coal-Associated Mineral Occurences Likely to be Factor in Long Range Air Pollution Considerations", West Virginia University School of Mines-Coal Research Bur. Tech. Report 17, 13 p. (Oct 1965).

402 Katz, M., and Ross, C. R., "Ambient Air Quality Standards in Relation to Fuel Combustion Products", Proc. First Conf. on Fuel Technology in Canada, p. 325-355 (May 21-23 1963).

403 McMichael, H. E., "Flue Gas Analysis - Sampling, Measurement, Utility", ISA - Nat. Power Instrumentation Symposium - 5th - Proce.,p. 91-99 (1962).

404 Nonhebel, G., "Heat Content of Water Vapour in Flue Gas", Journal Inst. of Fuel, V. 36, no. 267, p. 14[illegible]-147 (Apr 1963).

405 Hissink, M., "Instrument for Determining Sulphur Oxides in Flue Gases", Journal Inst. of Fuel, V. 36, no. 272, p. 373-376 (Sep 1963).

406 Whitby, K. T., and Liu, B.Y.H., "Polystyrene Aerosols - Electrical Charge and Residue Size Distribution", Atmospheric Environment, V. 2, no. 2, p. 103-116 (Mar 1968).

407 George, R. E., and Chass, R. L., "Control of Contaminant Emissions from Fossil Fuel-Fired Boilers", APCA Journal, V. 17, no. 6, p. 392-395 (1967).

408 Caretto, L. S., "Chemical Analysis of Air Pollution Sources", California University College of Eng., Combustion-Generated Air Pollution, 34 p., (Jun 1967).

409 Mueller, P. K., "Detection and Analysis of Atmospheric Pollutants", California University College of Eng., Combustion-Generated Air Pollution, 37 p., (Jun 1967).

410 Sawyer,R. F., "Fundamentals of Combustion", California University College of Eng., Combustion - Generated Air Pollution, 38 p. (Jun 1967).

411 Thomas, J. F., "Airborne Soot Characteristics from Combustion", California University College of Eng., Combustion - Generated Air Pollution, 20 p., (Jun 1967).

412-1 Hitchcock, L. B., "A Brief Highlight of Apparent Scope and Character of Research Requirements", Research Symposium to Advance Management & Conservation of Air Resources, Engineering Foundation, Co-ordinating Committee on Air Pollution, N.Y. (Mar 1962).

412-2 MacKenzie, V. G., "Research Needs in Improvement of Survey Technique, The Use of Monitoring, and the Correlation of Specific Emission Concentration with Ambient Air Quality", Research Symposium to Advance Management & Conservation of Air Resources, Engineering Foundation, Co-ordinating Committee on Air Pollution, N.Y. (Mar 1962).

412-3 McKee, H. C., "Research Needs in the Reproduction of Controlled Atmospheres Containing Controlled Quantities of Pollutants", Research Symposium to Advance Management & Conservation of Air Resources, Engineering Foundation, Co-ordinating Committee on Air Pollutants, N.Y. (Mar 1962).

412-4 Rossano, A. T., Jr., "Research Needs in Instrumentation for Sampling and Analysis", Research Symposium to Advance Management & Conservation of Air Resources, Engineering Foundation, Co-ordinating Committee on Air Pollutants, N.Y. (Mar 1962).

412-5 McCage, L. C., "The Shortcomings of Existing Diagnostic Tools", Research Symposium to Advance Management & Conservation of Air Resources, Engineering Foundation, Co-ordinating Committee on Air Pollutants, N.Y. (Mar 1962).

413 Cuffe, S. T, Gerstle, R. W., Orning, A. A., and Schwartz, C.H., "Air Pollutant Emissions from Coal-Fired Power Plants - Report No. 1", APCA Journal, V. 14, no. 9, p. 353-362 (Sep 1964).

414 Cuffe, S. T., and Gerstle, R. W., "Emissions from Coal-Fired Power Plants: A Comprehensive Summary", U.S. Public Health Service Pub. No. 999-AP-35, 26 p. (1967).

415 Gerstle, R. W., Cuffe, S. T., Orning, A. A., and Schwartz, C. H., "Air Pollutant Emissions from Coal-Fired Power Plants, Report No. 2", APCA Journal, V. 15, no. 2, p. 59-64 (Feb 1965).

416 Bovier, R. F., "Sulfur-Smoke Removal System", Am. Power Conf. Proc., V. 26, p. 138-144 (1964).

417 Ludwig, F. L., and Robinson, E., "Size Distribution Studies with the Aerosol Spectrometer", APCA Journal, V. 15, no. 3, p. 102-105 (Mar 1965).

418 Thomas, M. D., "Review of Recent Studies of Sulfur Oxides as Air Pollutants", APCA Journal, V. 14, no. 12, p. 517-520 (Dec 1964).

419 Gruber, C. W., and Schumann, C. E., "Objective Measurement of Smoke from Combustion Sources", Am. Chem. Soc. Div. of Fuel Chem., V. 10, no. 1, p. 57-64, Papers for meeting March 22-31, 1966.

420 Hanby, W. I., "The Effect of Gaseous Oscillations on the Combustion Rate of Solid Fuel Particles", Fuel Soc. Journal, Univ. of Sheffield, V. 18, p. 44-49 (1967).

421 Hedley, A. B., and Leesley, M. E., "Burning Characteristics of Pulverized Coal", Journal Inst. of Fuel, V. 38, no. 298, p. 492-500 (1965).

422 Anon, "Information Required for Selection of Electrostatic and Combination Fly Ash Collectors - Methods of Analysis for Chemical, Physical, and Electrical Properties of Fly Ash", APCA Journal, V. 15, no. 6, p. 256-260 (Jun 1965).

423 Jenkinson, J. R., "Sulfur Oxide Reactions", Mech. Corrosion Fuel Impurities, Proc. Intern. Conf. Marchwood, near Southampton, Hampshire, Engl, p. 443-450 (1963).

424 Penzias, G. J., "Spectroscopic Measurements of Flame Radiation for Improved Combustion Control", ISA - National Power Instrumentation Symp., 9th - Proc., p. 51-58 (May 16-18 1966).

425 Raco, R. J., and Peskin, R. L., "High Voltage, Low Frequency Atomization of Fuel Oil", ASHRAE Trans., V. 75, pt 1, Paper 2099, p. 111-117 (1969).

426 Roast, C. A., "Smut Emission", Journal Inst. of Fuel, V. 36, no. 266, p. 115-117 (Mar 1963).

427 Robinson, M. "Turbulent Gas Flow and Electrostatic Precipitation", APCA Journal, V. 18, no. 4, p. 235-239 (Apr 1968).

428 Third, A. D., "The Aim of Chimney Design", Eng. & Boiler House Rev., V. 82, no. 5, p. 124-128 (May 1967).

429 Thomas, F. W., Carpenter, S. B., and Gartrell, F. E., "Stacks - How High?", APCA Journal, V. 13, no. 5, p. 198-204 (May 1963).

430 Croome, D. J., "Chimney Design", Instn. Heating & Vent. Engineers Journal, V. 34, p. 165-175 (Sep 1966).

431 Crowe, C. T., Nicholls, J. A., and Morrison, R. B., "Drag Coefficients of Inert and Burning Particles Accelerating in Gas Streams", Combustion Inst.- 9th Symp. on Combustion (1952).

432 Delange, J. E., "Evaluating Dust Arresting Equipment on Large Coal-Fired Steam Generators", APCA Journal, V. 18, no. 2, p. 95-97, (Feb 1968).

433 Dunningham, A. C., "Practical Application of Fuel Oil in Industry", Steam & Heating Engr., V. 33, p. 6-11 (Dec 1963), p. 27-29 (Jan 1964), p. 22-27 (Feb 1964), p. 38-41 (Mar 1964).

434 Busby, H. G. T., and Darby, K., "Efficiency of Electrostatic Precipitators as Affected by the Properties and Combustion of Coal", Journal Inst. of Fuel, V. 36, no. 268, p. 184-97 (May 1963).

435 Cass, R. A., "Smoke Control Design", Journal of Cellular Plastics, V. 3, no. 1, p. 41-43 (Jan 1967).

436 Ciesielski, R., "Chimneys and Cooling Towers", Int. Assoc. for Shell Structures, Bul. No. 31, p. 13-29 (Sep 1967).

437 Collins, J. O., and Cyphers, E. B., "How Effective Are Additives in Oil-Fired Power Generating Equipment", ASME - Paper 64-PWR-1 for meeting Sept. 27 - Oct. 1, 1964.

438 Cummings, W. G., Redfearn, M. W., and Jones, W. R., "Air Pollution by Sulphur Dioxide:III: Effect of Increased Chimney Height on Ground Level Concentrations of Sulphur Dioxide", Journal Inst. of Fuel, V. 38, no. 297, p. 437 - 442 (1965).

439 Meredith, H. H., Jr., "Desulfurization of Caribbean Fuel", APCA Journal, V. 17, no. 11, p. 719-723 (Nov 1967).

440 Anon, "Monitoring Flue Dust", Measurement & Control, V. 2, no. 1, p. 16-20 (Jan 1963).

441 Narasimhan, K. S., and Foster, P.J., "The Rate of Growth of Soot in Turbulent Flow with Combustion Products and Methane", Symp. Combust., 10th, Univ. of Cambridge, Cambridge, Eng., 1964, p. 253-257 (1965).

442 Nature and Distribution of Particles of Various Sizes in Fly Ash:, U.S. Waterways Experiment Station, Tech. Report 6 - 583, 27 p. (Nov 1961).

443 Nelson, F., and Shenfeld, L., "Economics, Engineering and Air Pollution in the Design of Large Chimneys", APCA Journal, V. 15, no. 8, p. 355-361 (Aug 1965).

444 Ramsden, A. R., "Application of Electron Microscopy to the Study of Pulverized-Coal Combustion and Fly-Ash Formation", Journal Inst. of Fuel, V. 41, p. 451-454 (Dec 1968).

445 Drake, P. F., and Hubbard, E. H., "Combustion System Aerodynamics and Their Effect on the Burning of Heavy Fuel Oil, Journal Inst. of Fuel, V. 39, no. 302, p. 98-109 (Mar 1966).

446 Finfer, E. Z., "Fuel Oil Additives for Controlling Air Contaminant Emissions", APCA Journal, V. 17, no. 1, p. 43-45 (Jan 1967).

447 Finfer, E. Z, "Some Technical and Economic Aspects of Residual Fuel Oil Desulfurization", *APCA Journal*, V. 15, no. 10, p. 485-488 (Oct 1965).

448 Fohl, T., "Optimization of Flow for Forcing Stack Wastes to High Altitudes", *APCA Journal*, V. 17, no. 11, p. 730-733 (Nov 1967).

449 Glebovskaya, E. A., and Bolishakov, G. F., "Primenenie Infrakrasnoi Spektrometrii v Issledovanii Sernistykh Soedinenii Nefteproduktov", *Industrial Laboratory*, V. 29, no. 2, p. 156-159 (Feb 1963).

450 Schleusener, S. A., and Read, A. A., "A Gas Laser Small Particle Detector", *Proc. of the National Electric Conf.*, V. 21, p. 186-190 (Oct 1965).

451 Kirov, N.Y., "Sulfur in Oil Fuels - Its Effects in Combustion", *Journal Inst. of Fuel*, V. 35, no. 261, p. 426-431 (Oct 1962).

452 Klyachko, L. A., "Ignition of an Aggregate of Particles During Heterogeneous Reaction", *Pyrodynamics*, V. 6, no. 1, p. 29-38 (Jan 1968).

453 Kneen, T., and Strauss, W., "Deposition of Dust from Turbulent Gas Streams", *Atmospheric Environment*, V. 3, no. 1, p. 55-67 (Jan 1969).

454 Levaggi, D. A., and Feldwein, M., "Rapid Method for Determination of Sulfur in Fuel Oil by Schoniger Oxygen Flask Method", *APCA Journal*, V. 13, no. 8, p. 380, 387 (Aug 1963).

455 MacFarlane, J. J., "The Formation of SO_3 in the Combustion Products from Petroleum Fuel Oils", *Journal Inst. of Fuel*, V. 35, no. 262, p. 502-502, (1962).

456 Risk, J. B., Murray, F. E., "Continuous Recording of Sulfurous Gases Concentrations in Flue Gases", (Journal & Date Unknown).

457 Ryason, P. R., and Harkins, J., "Studies on a New Method of Simultaneously Removing Sulfur Dioxide and Oxides of Nitrogen from Combustion Gases", *APCA Journal*, V. 17, no. 12, p. 796-799 (De 1967).

458 Strauss, W., and Lancaster, B. W., "Prediction of Effectiveness of Gas Cleaning Methods at High Temperatures and Pressures", *Atmospheric Environment*, V. 2, no. 2. p. 135-144 (Mar 1968).

459 Parson, R. H., "Useful Information from Flue Gases", *Junior Instn. Engrs. Journal*, V. 73, pt 3, p. 64-75 (Dec 1962).

460 Barkovitz, W. E., and Ragland, B., "Fuel Savings and Air Pollution Control Through Selective Reinjection of Fly Ash", *National Engineer*, V. 67, no. 8, p. 8-9 (1963).

461 Batch, B. A., "The Application of an Electronic Particle Counter to Size Analysis of Pulverized Coal and Fly-Ash", *Journal of Inst. of Fuel*, V. 37, no. 285, p. 455-461 (Oct 1964).

462 Belyea, H. A., and Holland, W. J., "Flame Temperature in Oil-Fired Fuel-Burning Equipment and Its Relationship to Carbonaceous Particulate Emissions", APCA Journal, V. 17, no. 5, p. 320-323 (May 1967).

463 Bird, R. J., and Small, N.J.H., "The Combustion of Heavy Fuel Oil; Some Observations on Carbonaceous Droplet Residues and on the Ash From the Gas Stream, Journal Inst. of Petroleum, V. 51, p. 71-77 (1965).

464 Borgwardt, R. H., Harrington, R. E., and Spaite, P. W., "Filtration Characteristics of Fly Ash from a Pulverized Coal-Fired Power Plant", APCA Journal, V. 18, no. 6, p. 387-390 (Jun 1968).

465 Bunz, P., Neipenberg, H. P., and Rendle, L. K., "Influence of Fuel Oil Characteristics and Combustion Conditions on Flue Gas Properties in Water-Tube Boilers", Inst. of Fuel, Journal, V. 40, no. 320, 406-416 (Sep 1967).

466 Fiocco, G., and Grams, G., "Optical Radar Observations of Mesospheric Aerosols in Norway During the Summer 1966", Journal of Geophysical Research, V. 74, no. 10, p. 2453-2458 (May 1969).

467 Knowles, D.J., "Liquid and Gaseous Waster Effluent Sampling and Monitoring", Nuclear Safety, V. 7, no. 1, p. 52-56 (1965).

468 Drozin, V. G., and DeDeo, "Size Distribution in Aerosols Determined by Settling of Charged Particles", Columbia University, N.Y., Clearinghouse No. NYO-4657, 61 p. (1955).

469 Mitchell, R. I., and Pilcher, J. M., "Design and Calibration of an Improved Cascade Impactor for Size Analysis of Aerosols", 5th Atomic Energy Commission Air Cleaning Conference, June 24-27, 1957, Harvard Univ., Boston, Mass., Clearinghouse No. TID 7551, p 67-84 (1957).

470 Anon, "Selected Methods for the Measurement of Air Pollution", Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio (Pub-999-AP-11), Clearinghouse No. PB 169 677 (May 1965).

471 Sanders, C., and Thompson, J. R., Jr., "An Evaluation of the Smoke-Wire Technique for Measuring Velocities in Air", Mississipi State University, Clearinghouse No. AD 652 275 (Mar 1967).

472 Gerber, H., "Automatic Counting of Atmospheric Aerosols Collected with the Goetz Ultracentrifuge", Army Electronic Command, Fort Monmouth, N.J., Clearinghouse No. AD 658 667 (Jun 1967).

473 Dunn, J. F., Jr., Foster, A. R., Moring, T. J., Jr., Nardone, L. J., Swanson, J. L., and Zelinski, J.J., "Investigation of the Light Scattering Technique for Counting and Size Determination of Micron-Sized Meteorites", Northeastern University, Boston, Mass,. Clearinghouse No. AD 666 703 (Oct 1967).

474 Shahrokhi, F., and Wolf, P., "Mie-Scattering Function", University of Tennessee, Tullahoma, Clearinghouse No. N 68-21227 (Apr 1968).

475 Kriebel, A. R., "Design and Calibration of a Total-Pressure Probe for Dust-Laden Air, Stanford Research Inst., Menlo Park, Calif. Clearinghouse No. AD 267 172 (Jul 1959).

476 Anon, "Micrometeorology, Aerosols, and Air Pollution Bibliography", Library of Congress, Washington, D. C., Clearinghouse No. AD 403 864 (Apr 1963).

477 Fraser, R. S., "Scattering Properties of Atmospheric Aerosols", University of California, Los Angeles, Sci. Rep. No. 2, Clearinghouse No. AD 233 288 (1959).

478 Bokhoven, C., and Niessen, H.J.L., "The Continuous Monitoring of Traces of SO_2 in Air on the Basis of Discoloration of the Starch Iodine Reagent with Prior Elimination of Interfering Compounds", Int. J. Air Wat. Poll., V. 10, p. 233-243 (Apr 1966).

479 Gussman, R. A., and Gordon, D., "Notes on the Modification and Use of a Cascade Impactor for Sampling in Ducts", American Industrial Hygiene Assoc. Journal, V. 27, p. 252-255 (May-Jun 1966).

480 Hamilton, P. M., "The Use of Lidar in Air Pollution Studies", Int. J. Air Wat. Poll., V. 10, no. 6-7, p. 427-434 (Jun-Jul 1966).

481 Barrett, R. E., Moody, J. W., and Locklin, D. W., "Preparation and Firing of Emulsions of No. 2 Fuel Oil and Water", Battelle Memorial Institute, Columbus, Ohio, Clearinghouse No. PB 189 075 (1968).

482 Silverman, M. D., Truitt, J., Browning, W. E., Jr., and Franzen, L. F., "Characterization of Radioactive Particulate Aerosols by the Fibrous Filter Analyzer", Oak Ridge National Laboratory, Tenn. Clearinghouse No. ORNL-4047 (Mar 1967).

483 Ward, J., "Laser Fog Disdrometer System", Technical Operations, Inc. Burlington, Mass., Clearinghouse No. AD 656 487 (Jun 1967).

484 Lockhart, L. B., Jr., Patterson, R. L., Jr., and Saunders, A. W., Jr., "Filter Pack Technique for Classifying Radioactive Aerosols by Particle Size, Part 3", Naval Research Lab., Washington, D. C., Clearinghouse No. AD 620 354 (Jul 1965).

485 Lucas, D. H., and Snowsill, W. L., "Some Developments in Dust Pollution Measurement", Atmospheric Environment, V. 1, p. 619-636 (1967).

486 Crosse, P. A. E., Lucas, D. H., and Snowsill, W. L., "The Measurement of Dust Nuisance Emitted by Chimneys", Int. J. Air Wat. Poll., V. 4, p. 212-224 (1961).

487 Crosse, P. A. E., Lucas, D. H., and Snowsill, W. L., "Design of an "Everclean Window" for the Observation of the Optical Density of Flue Gas", Journal Inst. of Fuel, V. 34, no. 250, p. 503-505 (1961).

488 Watson, D., "Interrelation Between Sulphur Oxides and Soot in the Combustion Appliance and Stack", Fuel Society Journal, Univ. of Shefield, V. 11, p. 48-57 (1960).

489 Ushakov, S. G., "Designing Manifolds for Uniform Distribution of Dust-Laden Gas Flow to Different Branches", Thermal Engineering, no. 7, p. 56-59, (Jul 1967).

490 Vnukov, A. K., Goikhman, A. A., Madoyan, L. G., and Migalin, Y.A., "Determination of Unburnt Carbon When Burning Fuel Oil", Thermal Eng. (Engl. Trans.), no. 9, p. 61-64 (1966).

491 Yungman, V. S., Gurvich, L.V., and Rtishcheva, N. P., "The Influence of Potassium Seeding on Thermodynamic Properties of Combustion Products of Natural Fuels", Fourth ASME-Symp. on Thermophysical Properties - Proc., p. 222-226, April 1-4, 1968.

492 Jarvis, W. D., and Austin, L. G., "Routine Surveys of Atmospheric Pollution by Dust and Sulfur Dioxide Around Power Stations of the Central Electricity Authority", Journal Inst. of Fuel, V. 30, p. 435-446 (1967).

493 Mott, R. A., and Parramore K., "The Determination of Sulfur Trioxide in Flue Gases, I.", Journal Inst. of Fuel, V. 30, p. 123-126 (1957).

494 Hawksley, P.G.W., Badzioch, S., and Blackett, J. H., "Improved Sampling Equipment for Solids in Flue Gases", Journal Inst. of Fuel, V. 31, p. 147-160 (1958).

495 Haagen-Smit, A. J., "Studies of Air-Pollution Control by Southern California Edison Company", APCA Journal, V. 7, no. 4, p. 251-255 (1958).

496 Shale, C. C., Holden, J. H., and Fasching, G. E., "Electrical Resistability of Fly Ash at Temperatures to 1,500°F", U. S. Bureau of Mines, Publication 7041, 17 p. (1968).

497 Hudy, J., Jr., and Deurbrouck, A. W., "Evaluation of Continuous Recording X-ray Ash Meter",U. S. Bureau of Mines, Publication 7101, 20 p. (1968).

498 Demeter, J. J., and Bienstock, D., "Sulfur Retention in Anthracite Ash", U. S. Bureau of Mines, Publication 7160, 12 p., (1968).

499 Ozolins, G., and Rehmann, C., "Air Pollutant Emission Inventory of Northwest Indiana, A Preliminary Survey, NAPCA, Raleigh, N. C., Pub. APTD 68-4 (1966).

500 Anon, "A Compilation of Selected Air Pollution Emission Control Regulations and Ordinance" U. S. Dept. HEW, Public Health Service, Pub. 999-AP-43 (1968).

501 Bayliss, R. J., and Whaite, H. M., "A Study of the Radium Alpha-Activity of Coal, Ash, and Particulate Emission at a Sydney Power Station", Int. J. Air Wat. Poll., V. 10, no. 11-12, p. 813-819 (1966).

502 Davies, C. N., "Movement of Dust Particles Near a Horizontal Cylinder Containing a Sampling Orifice", British Journal of Applied Physics, V. 18, no. 5, p. 653-656 (May 1967).

503 Ellison, J. Mck., "The Nature of Air Pollution and the Methods Available for Measuring It", Bull. WHO (Geneva), V. 32, no. 3, p. 399-409 (1965).

504 Dmitriev, M. T., and Kitrosskii, N. A., "Ionization Methods for the Determination of Atmospheric Pollutants", Hygiene Sanit. (Engl. Trans.), V. 31, no. 7-9, p. 63-68 (Jul-Sep 1966).

505 Goetz, A., "An Instrument for the Quantitative Separation and Size-Classification of Air-Borne Particulate Matter Down to 0.2 Micron", Geopfis. Pura Appl., V. 36, p. 49-69 (1957).

506 Sehmel, G. A., "Errors in the Subisokinetic Sampling of an Air Stream", Ann. Occupational Hygiene,(London), V. 10, no. 2, p. 73-82 (Apr 1967).

507 Sehmel, G. A., "Estimation of Airstream Concentrations of Particulates from Subisokinetically Obtained Filter Samples", American Industrial Hygiene Assoc. Journal, V. 28, no. 3, p. 243-253 (May-Jun 1967).

508 Lundgren, D., and Calvert, S., "Aerosol Sampling with a Side Port Probe", American Industrial Hygiene Assoc. Journal, V. 28, no. 3, p. 208-215 (May-Jun 1967).

509 Jung, C., "The Size Distribution and Aging of Natural Aerosols as Determined from Electrical and Optical Data on the Atmosphere", Journal of Meteorology, V. 12, p. 13-25 (1955).

510 Sallman, C. M., "Check Stack Size During Fuel Conversion", Power, V. 113, no. 7, p. 57 (Jul 1969).

511 Gerstle, R. W., "How Much Pollutant is Discharged?", Power, V. 113, no. 1, p. 63-65 (Jan 1969).

512 Peterson, C. C., Jr., Dailey, W. V., and Amrhein, W. G., "Applying Nondispersive Infrared to Analyze Polluted Stack Gases", Instrumentation Technology, V. 14, no. 8, p. 45-58 (Aug 1967).

513 Lancaster, B. W., and Strauss, W., "Angle Scanning Mounting for a Light Scattering Photometer", Journal of Scientific Instruments, V. 43, p. 395-396 (Jun 1966).

514 Proctor, T. D., "A Laser Technique for the Measurement of Aerosols", Journal of Scientific Instruments (Journal of Physics E.), Ser. 2, V. 1, no. 6, p. 631-635 (Jun 1968).

515 Gucker, F. T., and Tuma, J., "Influence of the Collecting Lens Aperature on the Light-Scattering Diagrams from Single Aerosol Particles", Contribution No. 0000 from the Chemical Laboratory of Indiana University, Bloomington, Indiana, 47401.

516 Van Lighten, R. F., "Holographic Microscopy and Small Particles", American Laboratory, p. 23-26, (Apr 1969).

517 Martin, J. S., "Walter C. McCrone Associates Laboratory Profile", American Laboratory, p. 64-67 (Apr 1969).

518 Hall, A. E., "Literature Review - Particles Size Determination", (further reference unavailable).

519 Gruber, C. W., and Alpaugh, E. L., "The Automatic Filter Paper Sampler in an Air Pollution Measurement Program", APCA Annual Meeting Paper No. 54-5, Chattanooga, Tenn., Chattanooga, Tenn., May 3-6, 1954.

520 Crumley, P. H., and Fletcher, A. W., "The Emission of Sulphur Gases from a Domestic Solid-Fuel Appliance", Journal Inst. of Fuel, V. 30, p. 608-612 (1957).

521 Fielder, R. S., Jackson, P. J., and Raask, E., "Determination of Sulfur Trioxide and Sulfur Dioxide in Flue Gases", Journal Inst. of Fuel, V. 33, p. 84-90 (1960).

522 Drozin, V. G., and LaMer, V. K., "The Determination of the Particle Size Distribution of Aerosols by Precipitation of Charged Particles", Journal of Colloid Science, V. 14, p. 74-90 (1959).

523 Grohse, E. S., and Saline, L. E., "Atmospheric Pollution the Role Played by Combustion Processes", APCA Journal, V. 8, p. 255-267 (1958).

524 Alexander, P. A., Fielder, R. S., Jackson, P. J., Raask, E., and Williams, T. B., "Acid Deposition in Oil-Fired Boilers: Comparative Trials of Additives and Testing Techniques", Journal Inst. of Fuel, V. 34, p. 53-72 (1961).

525 Crumley, P. H., Howe, H., and Wilson, D.S., "Automatic Determination of Sulfur Trioxide in Flue Gases", Journal Inst. of Fuel, V. 31, p. 378-382 (1958).

526 Austin, H. C., "Atmospheric Pollution Problem of the Public Utility Industry. Sources of Potential Air Pollutants", APCA Journal, V. 10, p. 292-294 (1960).

527 Craxford, S. R., "Air Pollution from Power Stations", Smokeless Air (London), V. 36, p. 123-128 (1965).

528 Friedlander, S. K., and Pasceri, R. E., "Measurements of Particle Size Distribution of the Atmospheric Aerosol; I. Introduction and Experimental Methods", Journal of Atmospheric Sciences, V. 22, p. 571-576 (1965).

529 Ferguson, J. S., and Sheridan, E. G., "Some Applications of Microscopy to Air Pollution", APCA Journal, V. 11, no. 12, p. 669-672 (Dec. 1966).

530 Chapman, R. L., "Air Pollution Control System", Instruments & Control Systems, V. 41, no. 8, p. 79-82 (Aug 1968).

531 Goyer, G. G., and Watson, R. D., "Laser Techniques for Observing the Upper Atmosphere", Bull. American Meteorological Society, V. 49, (Sep 1968).

532 Juntgen, H., and van Heek, K. H., "Gas Release from Coal as a Function of the Rate of Heating", Fuel, V. 47, no. 2, p. 103-117 (Mar 1968).

533 Hangebrauck, R. P., and Henschel, D. B., "Fluid Bed Combustion, Its Potential and Its R & D Requirements", British Coal Utilities Research Assoc. Monthly Bulletin, V. 33, no. 5, p. 106-110 (May 1969).

534 Hicks, D., "Oxides of Nitrogen", British Coal Utilities Research Assoc., Gaz., V. 62, p. 7-11.

535 Englemann, R. J., "Calculation of Precipitation Scavenging of Particulates and Gases from the Atmosphere", Nuclear Safety, V. 7, no. 3, p. 354-364 (1966).

536 Thompson, B. J., "Advantages and Problems of Coherence as Applied to Photographic Situations, SPIE, Journal, V. 4, p. 7-11 (Oct-Nov 1965).

537 Wilkinson, T.J., and Clarke, D. G., "Problems Encountered with the Use of High Sulfur Content Fuel Oils at Marchwood Generating Station and Experience with Chemical Additives", Journal Inst. of Fuel, V. 32, p. 61-72 (1959).

538 Rendle, L. K., and Wilsdon, R. D., "Prevention of Acid Condensation in Oil-Fired Boilers", Journal Inst. of Fuel, V. 29, p. 373-380 (1956).

539 Nelson, H. W., and Lyons, C. J., "Sources and Control of Sulfur-Bearing Pollutants", APCA Journal, V. 7, p. 187-193 (1957).

540 Barnhart, D.H., and Diehl, E. K., "Control of Nitrogen Oxides in Boiler Flue Gases by Two-Stage Combustion", APCA Journal, V. 10, p. 397-406 (1960).

541 Lockhart, L. B., Jr., Patterson, R. L., Jr., and Saunders, A. W., Jr., "Filter Pack Techniques for Classifying Radioactive Aerosols by Particle Size, Part 2", Naval Research Lab., Washington, D. C., Clearinghouse No. AD 608 720 (Oct 1964).

542 Culkowski, W. M., "Calculations of the Deposition of Aerosols from Elevated Sources", U.S. Weather Bureau, Oak Ridge, Tenn., Clearinghouse No. ORO-171 (1958).

543 Dennis, R., Doyle, A. W., Gordon, D., Gussman, R. A., Honnel, C. O., and Sacco, A. M., "Aerosol Dissemination Assessment", GCA Corp., Bedford, Mass., Clearinghouse No. AD 813 342 (Apr 1967).

544 LeClare, P. C., Breslin, A. J., and Ong, L.D.Y., "Factors Affecting the Accuracy of Average Dust Concentration Measurements", American Industrial Hygiene Assoc. Journal, V. 30, no. 4, p. 386-393 (Jul-Aug 1969).

545 Knuth, R. H., "Recalibration of Size-Selective Samplers", American Industrial Hygiene Assoc. Journal, V. 30, no. 4, p. 379-385 (Jul-Aug 1969).

546 Goetz, A., "The Aerosol Spectrometer - A New Instrument for the Analysis of Air-Borne Particles in the Submicron Range", Public Works, V. 90, no. 2, p. 91-93 (Feb 1959).

547 Granville, R. H., and Jaffrey, W. G., "Dust and Grit in Flue Gases - Gravimetric Sampling of Solid Particles", Engineering, V. 187, p.285-288 (Feb 1959).

548 Monkhouse, A.C., "The Combination of Coal", Chemistry & Industry, p. 52-64 (Jan 1958).

549 Bredl, J., and Grieve, T.W., "A Thermal Precipitator for the Gravimetric Estimation of Solid Particles in Flue Gases", Journal of Scientific Instruments, V. 28, p. 21-23 (1951).

550 Kaiser, E. R., "Stack Dust: Here's What Affects It", Power, V. 95, no. 6, p. 92-95 (Jun 1951).

551 Kaiser, E. "Dust Emission from Coal-Fired Boiler Furnaces", Combustion, V. 22, p. 53-57 (May 1951).

552 Grindell, D. H., "Atmospheric Pollution by Solid Particles, Measuring Significant Particle Surface Area by Charge Transfer", Engineering, V. 187, p. 1350-1351 (Mar 1959).

553 Dussourd, J. L., and Shapiro, A. H., "A Deceleration Probe for Measuring Stagnation Pressure and Velocity of a Particle-Laden Gas Stream", 1955 Heat Transfer and Fluid Mechanics Inst., University of California, Los Angeles, Calif. (Jun 1955).

554 Grindell, D. H., "Monitoring Smoke and Flue-Dust Emission", AEI Eng., V. 2, no. 5 (1962).

555 Nader, J. S., and Allen, D. R., "A Mass Loading and Radioactivity Analyzer for Atmospheric Particulates", APCA Annual Meeting No. 52, Los Angeles, Calif. (Jun 1959).

556 Silverman, L., "Sampling of Industrial Stacks and Effluents for Atmospheric-Pollution Control", Proc. National Air Pollution Symposium 1949, V. 1, p. 55-60 (1951).

557 Gucker, F. T., Jr., "Determination of Concentration and Size of Particulate Matter by Light Scattering and Sonic Techniques", Proc. National Air Pollution Symposium, 1949, V. 1, 14-26 (1951).

558 Thomas, M. D., and Ivie, J., "Automatic Apparatus for the Determination of Small Concentrations of Sulfur Dioxide and Other Contaminants in the Atmosphere", Air Pollution, Louis C. McCabe, ed., Proc. U.S. Technical Conference on Air Pollution, 1950, p. 567-579 McGraw-Hill (1952).

559 O'Konski, C. T., Bitron, M.D., and Higuchi, W. I., "Light Scattering Instrumentation for Particle Size Distribution Measurements", American Society of Testing Materials, Spec. Tech. Pub. No. 250, p. 2-28 (1959).

560 Bush, A. F., "Instrumentation for Sampling and Analyzing Combustion Particles Using an Electron Microscope", Proc. 10th National Analytical Inst. Symp., San Francisco, 1964, p. 267-278.

561 Byran, R. J., "Instrumentation for Air Pollution", Instrumentation & Automation, V. 29, p. 2432-2438 (1956).

562 Katz, M., "The Standardization of Methods of Sampling and Analysis", International Clean Air Conf. Proc., London, 1959, p. 147-52 (1960).

563 DeMartini, F. E., "The Significance of Particulate Emissions in Community Air Pollution", Particulate Emissions, Proc. Symp. Air Pollution, Philadelphia, 1957, p. 3-20 (1958).

564 Sulzer, P.T., "The Prevention of Oil-Ash Deposition by Means of Fuel Additives", 4th World Petrol. Congr. Proc., Rome, Sect. VI, p. 223-46 (1955).

565 Fischer, L. J., "The Chemistry and Physics of Combustion Made Easy", Heating & Vent. Eng., V. 36, no. 424, p. 276-281 (Nov 1962).

566 Thomas, M. D., "The Present Status of the Development of Instrumentation for the Study of Air Pollution", Proc. National Air Pollution Symp., V. 2, p. 16-23 (1952).

567 Dobbins, R. A., "Remote Size Measurements of Particulate Products of Heterogeneous Combustion", 11th International Symp. on Combustion, Combustion Inst., Pittsburgh, Pa. (1967).

568 Parrent, G.B., Jr., and Thompson, B. J., "On the Fraunhofer (Far Field), Diffraction Patterns of Opaque and Transparent Object with Coherent Background", Opt. Acta., V. 11 (1964).

569 Collis, R. T. H., "Lidar: A New Atmospheric Probe", Royal Meteorological Society, Quarterly Journal, V. 92, p. 220-230 (1966).

570 Eldridge, R. G., "Haze and Fog Aerosol Distributions", Journal of Atmospheric Science, V. 23, p. 605-613 (1966).

571 Harris, F. S., Jr., and Sherman, G. C., "Laser Light Scattering and Aerosols", APCA Journal, V. 18, p. 659-660 (Oct 1968).

572 Brar, S. S., "Describes Technique for Trace Element Detection" APCA Journal, V. 18, p. 621 (Sep 1968).

573 McShane, W. P., and Bulba, E., "Automatic Stack Monitoring of a Basic Oxygen Furnace", APCA Journal, V. 18, no. 4, (Apr 1968).

574 Dennis, R., and Billings, C. E., "Aerosol Studies at GCA Technology Division", APCA Journal, V. 18, p. 687-688 (Oct 1968).

575 Gucker, F. T., Osborne, E. C., and Tuma, J., "Physical-Chemical Studies of Aerosols", APCA Journal, V. 18, p. 664-665 (Oct 1968).

576 Lieberman, A., and Jackson, H., "Aerosol Research at IIT Research Institute", APCA Journal, V. 18, p. 660-661 (Oct 1968).

577 Goetz, A., Stevenson, H.J. R., and Preining, O., "The Design and Performance of the Aerosol Spectrometer", APCA Journal, V. 10, no. 5, p. 378-383, 414, 416 (Oct 1960).

578 Martens, A. E., "Errors in Measurement and Counting of Particles Using Light Scattering", APCA Journal, V. 18, p. 661-663 (Oct 1968).

579 Mitchell, R. I., and Engdahl, R. B., "A Survey for Improved Methods for the Measurement of Particulate Concentration in Flowing Gas Streams" APCA Journal, V. 13, no. 11, p. 558-563 (1963).

580 Ogle, H.M., "Particle Counting Techniques Available for Aerosol Research", APCA Journal, V. 18, p. 657-659 (Oct 1968).

581 Mohnen, V. A., and Holtz, P., "The SUNYA-ASRC Aerosol Detector", APCA Journal, V. 18, p. 667-668 (Oct 1968).

582 Sasiadek, M., and Teisseyre, M., "Recherches sur la mesure du debit des melanges biphases de gaz et de charbon pulverise", Revue Generale de Thermique, V. 7, no.5, p. 267-279 (1968).

583 Fitton, A., "Ash and Atmospheric Pollution", Journal Inst. of Fuel, V. 25, p. 178-181 (1952).

584 Peterson, A. H., "Measurement of the Visibility Aspects of Air Pollution by Means of Light Scattering", APCA Journal, V. 5, p. 212, 247 (1956).

585 Wilcos, J. D., "Isokinetic Flow and Sampling", APCA Journal, V. 5, p. 226, 245 (1956).

586 Goetz, A., "The Application of the Concentrometer-Principle to the Determination of Aerosols", APCA Journal, V. 6, p. 72-76 (1956).

587 Richardson, J. F., and McLeman, M., "Pneumatic Conveying - Part II: Solids Velocities and Pressure Gradients in a One-Inch Horizontal Pipe", Trans. Inst.of Chemical Engineers, V. 38, p. 257-266 (1960).

588 Barker, K., and Corbett, P. F., "The Effect of Auxilliary Fuel Firing on the Sulfur Trioxide Content of Flue Gases from a Coal-Fired Boiler", Journal Inst. of Fuel, V. 27, p. 495-502 (1954).

589 Corbett, P. F., "The Sulfur Trioxide Content of the Combustion Gases from an Oil-Fired Water-Tube Boiler", Journal Inst. of Fuel,V. 26, p. 92-104 (1953).

590 Brown, R. L., "Some Coal Research Problem and Their Industrial Implications", Journal Inst. of Fuel, V. 29, P. 218-236 (1956).

591 Sambrook, K. H., "Fuel Oils, Their Efficient and Smokeless Combustion", Petroleum, V. 17, p. 56-61, 63 (1954).

592 Flint, D., Lindsay, A.W., and Littlejohn, R. F., "The Effect of Metal Oxide Smokes on the Sulfur Trioxide Content of Combustion Gases from Fuel Oils", Journal Inst. of Fuel, V. 26, p. 122-127 (1953).

593 Anon, Proceeding of the 4th Symposium on Remote Sensing Environment, 12-14 April 1966, Michigan University, Ann Arbor, Mich., Clearinghouse No. AD 638 919 (Jun 1966).

594 Nelson, W. L., "How to Combat High-Sulfur-Fuel Corrosion", Oil & Gas Journal, V. 56, p. 61-62 (Sep 1958).

595 Ferguson, J. S., and Sheridan, E. G., "Optical Microscopy as Applied to Air Pollution Studies - A Reference List", Public Health Service, National Center for Air Pollution Control, Cincinnati, Ohio, Publ. No. APTD-68-3, 10 p. (Mar 1968).

596 Swift, R. L., "Instruments for Air Pollution", *Air Engineering*, V. 2, no. 1, p. 27-30 (Jan 1960).

597 Harris, F. S., Jr., "Particle Characteristics from Light Scattering Measurements", *Tellus*, V. 21, no. 2, p. 223-229 (1969).

598 Mumma, V. K., Thomas, A. L., Jr., and Collins, R. H., III, "A Particle Size Analyzer for Aerosols", Army Biological Labs., Frederick, Md., Clearinghouse No. AD 636 858 (1962).

599 Lieberman, A., and Schipman, P., "Air-Pollution-Monitoring Instrumentation", NASA, Clearinghouse No. NASA SP 5072 (1969).

600 Blair, D. W., "Particle Damping of a Plane Acoustic Wave in Solid Propellant Combustion Gases", *AIAA Journal*, V. 1, p. 2625-2626 (1963).

601 Dobbins, R. A., "Measurement of Mean Particle Size in a Gas-Particle Flow", *AIAA Journal*, V. 1, p. 1940-1942 (1963).

602 Dobbins, R. A., and Jizmagian, G., "Particle Size Measurements Based on Use of Mean Scattering Cross Sections", *Optical Society of America Journal*, V. 56, p. 1351 (1966).

603 Dobbins, R. A., and Jizmagian, G., "Optical Scattering Cross Sections for Polydispersions of Dielectric Spheres", *Optical Society of America Journal*, V. 56, p. 1345 (1966).

604 Zink, J. W., and Delsasso, L. P., "Attenuation and Dispersion of Sound by Solid Particles Suspended in a Gas", *Acoustical Society of America Journal*, V. 30, p. 765-771 (1958).

605 Knudson, V. O., Wilson, J. V., and Anderson, N. S., "The Attenuation of Audible Sound in Fog and Smoke", *Acoustical Society of America Journal*, V. 20, p. 849-857 (1948).

606 McGreevy, G., "The Evaluation of the Performance of an Electrostatic Precipitator Using a Pollak-Nolan Nucleus Counter", *Atmospheric Environment*, V. 1, no. 2, p. 87-95 (1967).

607 Padovani, C. and Cappion, P., "Air Pollution by Heating Plant: Proposal for a New Reference Index for Emission Limit", *Atmospheric Environment*, V. 1, no. 5, p. 609-612 (1967).

608 Katz, J., "The Effective Collection of Fly Ash at Pulverized Coal-Fired Plants", APCA Journal, V. 15, no. 11, p. 525-528 (1965).

609 Hall, H. J., and Brown, R. F., "A New Electrostatic Liquid Cleaner", Lubrication Eng., V. 22, no. 12, p. 488-495 (1966).

610 Haagen-Smit, A. J., "Photochemistry and Smog", APCA Journal, V. 13, p. 444-446 (1963).

611 Gartrell, V. E., "Control of Air Pollution from Large Thermal Power Stations", Rev. Society Roy. Belge Ing. Ind., no. 11, p. 471-482 (1966).

612 Wang, G. K. M., "Instrument for Determining Sulfur Oxides in Flue Gases", Combustion, V. 38, no. 11, p. 46-49 (1967).

613 Tine, G., "Gas Sampling and Chemical Analysis in Combustion Processes", AGAR Dograph No. 47, 94 p. (1967).

614 Scarlett, B., "Particle Size Analysis, Chemical Process Engineering, V. 46, no. 4, p. 197-201 (1965).

615 Sinclair, D., "A New Photometer for Aerosol Particle Size Analysis", APCA Journal, V. 17, no. 2, p. 105-108 (1967).

616 Epstein, P. S., and Carhart, R. R., "The Absorption of Sound in Suspensions and Emulsions", Journal of the Acoustical Society of America, V. 25, p. 553-565 (1953).

617 Stober, W., and Zessack, U., "Zur Messung von Aerosol-Teilchengrossenspektren mit Hilfe von Zentifugalabscheidern", Zentbl. Biol. Aerosol-Forsch, V. 13, p. 263-281 (Dec 1966).

618 Harding, C. I., and Hendrickson, E. R., "Manual for Calibration and Use of High-Volume Air Samplers in Measurement of Suspended Particulate Matter", Florida Uni., Eng. & Indus. Experiment Station, Bul. 117, 18 p. (Aug 1964).

619 "Gas Analysis and Air Pollution", Sira Abstracts and Reviews, V. 23, p. 189-190 (Jun 1968).

620 Smith, W. A., "Atmospheric Emissions from Fuel Oil Combustion", U.S. Public Health Service, Pub. No. 999-AP-2 (Nov 1963).

621 Anon, "Air Sampling Instruments", Amer. Conf. of Governmental Industrial Hygienists (1962).

622 Anon., Plant Specifications (1970).

623 Friedrichs, K. H., "Experience with Impactors in Dust Measurements", Staub-Reinhalt der Luft (Engl. Trans.), V. 28, no. 5 (May 1968).

624 Walkenhorst, W., and Bruckmann, E., "Mineral Analysis of Suspended Dust Classified According to Particle Size", Staub-Reinhalt der Luft (Engl. Trans.), V. 26, p. 45-49 (May 1966).

625 Bennert, W., and Hilbig, G., "The Theory of the Coincidence Error for Digital Particle Size Analysis", Staub-Reinhalt der Luft (Engl. Trans.), V. 27, p. 24-29 (Apr 1967).

626 Hersch, P. A., "Controlled Addition of Experimental Pollutants to Air", APCA Journal, V. 19, no. 3, p. 164-172 (Mar 1969).

627 Pasceri, R. E., and Friedlander, S. K., "Measurements of the Particle Size Distribution of the Atmospheric Aerosols" II. Experimental Results and Discussion", Journal of Atmospheric Science, V. 22, p. 577-584 (1965).

628 Morgan, G. B., Golden, C., and Tabor, E. C., "New and Improved Procedures for Gas Sampling and Analysis in the National Air Sampling Network", APCA Journal, V. 17, no. 5, p. 300-304 (May 1967).

629 Hocheiser, S., Santner, J., and Ludmann, W. F., "The Effect of Analytical Method on Indicated Atmospheric SO_2 Concentration", APCA Journal,(Volume & Date Unknown).

630 Mitchell, R. F., "An Experimental Study of An Electrostatic Precipitator Used for the Collection and Sizing of Airborne Particulate Matter", Wright-Patterson Air Force Base, Dayton, Ohio, Clearinghouse No. AD 621 030 (1965).

631 Marteney, P. J., "Experimental Investigations of the Opacity of Small Particles", United Aircraft Corp., East Hartford, Conn., Clearinghouse No. N 65 20983 (1965).

632 Clarenburg, L. A., and Prince, L. H., "An Improved Instrument for Measurement of Gravimetric Aerosol Concentration", Staub-Reinhalt der Luft (Engl. Trans.), V. 23, no. 4, p. 234-236 (Apr 1963).

633 Trolinger, J. D., Belz, R. A., and Farmer, W. M., "Holographic Techniques for the Study of Dynamic Particle Fields", ARO, Inc., Clearinghouse No. AD 678 858 (Nov 1968).

634 Bourquin, K. R., and Shigemonto, F. H., "Investigation of Air-Flow Velocity by Laser Backscatter", Ames Research Center, Moffett Field, Calif., Clearinghouse No. N 68 20375 (Apr 1968).

635 Drozin, V. G., "The Determination of the Particle Size Distribution of Aerosols by Precipitation of Charged Particles", Columbia Univ., Univ. Microfilms, order no. 21782 (1957).

636 Dorian, P. B. "The Dielectric Properties of Aerosols", Indiana Univ., Univ. Microfilm, order no. 17948 (1954).

637 Crosse, P. A. E., Lucas, D. H., and Snowsill, W. L., "Instrument for Recording the Dust Nuisance by Chimneys", *Journal of Scientific Instruments*, V. 38, p. 12-17 (Jan 1961).

638 Rumpf, H., "The Particle Size Analysis of Industrial Dusts", *Staub-Reinhalt der Luft, (Engl. Trans.)*, V. 25, no. 1, p. 17-26 (Jan 1965).

639 Desler, H., "Determining the Pass-Function of the HS Konimeter for Particle Sizes Below 1 Micrometer with the Aid of Different Test Dusts", *Staub-Reinhalt der Luft (Engl. Trans.)*, V. 25, no. 2, p. 24-28 (Feb 1965).

640 Narjes, L., "The Use of New Zero-Pressure Probes for Quasi-Isokinetic Sampling in Steam-Power Plants", *Staub-Reinhalt der Luft (Engl. Trans.)*, V. 25, no. 4, p. 11-18 (Apr 1965).

641 Thieme, W., "Emission Measurements of Heavy-Duty Boilers for Solid Fuels", *Staub-Reinhalt der Luft (Engl. Trans.)*, V. 25, no. 6, p. 14-20 (Jun 1965).

642 Muller, E. "A Recording Method of Dust Measurement Based on the Diaphragm Filter", *Staub-Reinhalt der Luft*, V. 25, no. 7. p. 1-7 (Jul 1965).

643 Narjes, L., "Determining Flow Densities, Particle Segregations and Time-Conditioned Flow Fluctuations During the Pneumatic Conveyance of Bituminous Coal Dust by Means of the Zero-Pressure Probe", *Staub-Reinhalt der Luft (Engl. Trans.)*, V. 25, no. 7, p. 8-12 (Jul 1965).

644 Binek, B., "Sampling Finely Dispersed Aerosols for Electron-Microscopic Particle Analysis", *Staub-Reinhalt der Luft (Engl. Trans.)*, V. 25, no. 7, p. 13-18 (Jul 1965).

645 Fihrmann, H., "Recording Measurements of Gaseous Imission Concentrations with a New Analyzer" *Staub-Reinhalt der Luft (Engl. Trans.)*, V. 24, no. 7, p. 19-25 (Jul 1965).

646 Rost, D. "New Method of Particle Size Analysis with Membrane Filters", *Staub-Reinhalt der Luft (Engl. Trans.)*, V. 25, no. 8, p. 17-19 (Aug 1965).

647 Lahman, E. "Methods for Measuring Gaseous Air Pollutions", *Staub-Reinhalt der Luft (Engl. Trans.)*, V. 25, no. 9, p. 17-20 (Sep 1965).

648 Breuer, H., "The Technical Principles for Measuring Dust Impurities in Air", Staub-Reinhalt der Luft (Engl. Trans.), V. 25, no. 9, p. 23-30 (Sep 1965).

649 Stober, W., "Measuring Methods to Describe the Physical Properties of Aerosol Systems", Staub-Reinhalt der Luft (Engl. Trans.), V. 25, no. 9, p. 34-41 (Sep 1965).

650 Schiemann, G., "Reducing the Emissions of Small Oil-Firing Units with Special Emphasis on Control Methods", Staub-Reinhalt der Luft (Engl. Trans.), V. 25, no. 11, p. 2-16 (Nov 1965).

651 Elshout, A.J., "The Measurements of Dust and Gaseous Air Pollutions in the Vicinity of an Isolated Power Station", Staub-Reinhalt der Luft (Engl. Trans.), V. 25, no. 11, p. 37-44 (Nov 1965).

652 Simecek, J., "Microscopical Determination of Particle Size Distribution", Staub-Reinhalt der Luft (Engl. Trans.), V. 26, no. 4, p. 27-33 (Apr 1966).

653 Berner, A., "Determining the Distribution Function of an Aerosol by Means of Multi-Stage Cascade Impactors", Staub-Reinhalt der Luft Engl. Trans.), V. 26, no. 4, p. 34-36 (Apr 1966).

654 Friedrichs, K. H., "The Continuous Measurement of Particulate Air Pollution; Experience with the TM II Sampler", Staub-Reinhalt der Luft (Engl. Trans.),V. 26, no. 6, p. 17-21 (Jun 1966).

655 Muhlrad, W., "The Use of Zero Pressure Probes to Measure Dust Content in Pipe Conduits", Staub-Reinhalt der Luft (Engl. Trans.), V. 26, no. 7, p. 43-56 (Jul 1966).

656 Budzinski, K. "Investigating the Flow of Dust Particles at Probe Nozzles by Photographing the Particle Paths", Staub-Reinhalt der Luft (Engl. Trans.), V. 26, no. 7, p. 27-48 (Jul 1966).

657 Simecek, J., "Comparative Study of Methods for Determination of Particle Size", Staub-Reinhalt der Luft (Engl. Trans.), V. 26, no. 9, p. 18-26 (Sep 1966).

658 Grafe, K., and Hagen, J., "Minimum Stack Heights and Area Around Stack Within Which Buildings Must Be Considered", Staub-Reinhalt der Luft (Engl. Trans.), V. 26, no. 9, p. 41-43 (Sep 1966).

659 Schutz, A. "Possibilites for Recorded Dust Measurement and Dust Control", Staub-Reinhalt der Luft (Engl. Trans.), V. 26, no. 10, p. 1-8 (Oct 1966).

660 Kahnwald, H., "Dust Measurements in Flowing Gases", Staub-Reinhalt der Luft (Engl. Trans.), V. 26, no. 10, p. 20-22 (Oct 1966).

661 Baust, E., "Use of the Goetz Aerosol Spectrometer to Measure the Size Spectra of Polydispersed Aerosols", Staub-Reinhalt der Luft Engl. Trans.), V. 27, no. 4, p. 16-23 (Apr 1967).

662 Fauth, U., and Schule, W., "Gaseous and Solid Emissions from Oil-Fired Stoves", Staub-Reinhalt der Luft (Engl. Trans.), V. 27, no. 6, p. 1-11 (Jun 1967).

663 Simecek, J., "Comparative Investigation of Methods for Particle Size Determination", Staub-Reinhalt der Luft (Engl. Trans.), V. 27, no. 6, p. 33-37 (Jun 1967).

664 Pfefferkorn, H., and Blaschke, R., "Dust Analysis of the wir with the Scanning Electron Microscope 'Stereoscan'", Staub-Reinhalt der Luft (Engl. Trans.), V. 27, no. 8, p. 30-33 (Aug 1967).

665 Sundelof, L. O., "On the Accurate Calculation of Particle-Size Distributions in Aerosols from Impaction Data", Staub-Reinhalt der Luft (Engl. Trans.), V. 27, no. 8, p. 22-28 (Aug 1967).

666 Binek, B., and Dohnalova, B., "Using the Scintillation Spectrometer for Aerosols in Research and Industry", Staub-Reinhalt der Luft (Engl. Trans.), V. 27, no. 9, p. 1-7 (Sep 1967).

667 Winkel, G., "Flow Investigations with the Aid of the Thermistor, as Exemplified by its Use with the Sampling Probe", Staub-Reinhalt der Luft (Engl. Trans.), V. 27, no. 12, p. 46-50 (Dec 1967).

668 Thoenes, H. W., and Guse, W., "Latest State of Development of Instruments for the Continuous Monitoring of Gas Emissions", Staub-Reinhalt der Luft (Engl. Trans.), V. 28, no. 3, p. 53-62 (Mar 1968).

669 Davies, C. N., "The Sampling of Aerosols, The Entry of Aerosols into Sampling Tubes and Heads", Staub-Reinhalt der Luft, V. 28, no. 6, p. 1-9 (Jun 1968).

670 Martens, A. E., and Fuss, K. H., "An Optical Counter for Dust Particles", Staub-Reinhalt der Luft, V. 28, no. 6, p. 14-18 (Jun 1968).

671 Baust, E., "Evaluating the Precipitation of Polydisperse Aerosols in a Goetz Aerosol Spectrometer by the Light Scattering Methods", Staub-Reinhalt der Luft, V. 28, no. 6, p. 18-22 (Jun 1968).

672 Petrausch, D., and Schumann, G., "Size Spectroscopy of Radioactive Aerosols by Means of Electrostatic Precipitation", Staub-Reinhalt der Luft, V. 28, no. 8, p. 1-6 (Aug 1968).

673 Jacobi, W., Eichler, J., and Stolterfoht, N., "Particle Size Spectrometery of Aerosols by Light Scattering in a Laser Beam", Staub-Reinhalt der Luft, V. 28, no. 8, p. 15-22 (Aug 1968).

674 Geisel, W., "Calculating the Particle Size Distribution of a Dust by Means of Fractional Separation Efficiency Curves and Total Efficiency Curves", Staub-Reinhalt der Luft (Engl. Trans.), V. 28, no. 8, p. 25-28 (Aug 1968).

675 Simecek, J., and Kubalek, J., "Experience with Cyclone Preseparation in Dust Sampling", Staub-Reinhalt der Luft (Engl. Trans.), V. 28, no. 10, p. 24-31 (Oct 1968).

676 Hess, W., "Emissions from Oil Firings in Zurich", Staub-Reinhalt der Luft (Engl. Trans.), V. 25, p. 14-16 (Nov 1965).

677 Thieme, W., "Measures for Reducing Emission from Domestic Hearths Using Solid Fuels", Staub-Reinhalt der Luft (Engl. Trans.), V. 25, no. 11, p. 10-13 (Nov 1965).

678 Kielich, S., "Linear and Nonlinear Light Scattering in Colloidal Media", Journal of Colloid & Interface Science, V. 27, no. 3, p. 432-441 (1968).

679 Rowell, R. L., Wallace, T. P., and Kratohvil, J. P., "Determination of the Number Concentration of Polydisperse Colloidal Spheres by Light Scattering", Journal of Colloid & Interface Science, V. 26, no. 4, p. 494-499 (1968).

680 Whitby, K. T., and Liu, B. Y. H., "Generation of Countable Pulses by High Concentrations of Subcountable Sized Particles in the Sensing Volume of Optical Counters", Journal of Colloid & Interface Science, V. 25, no. 4, p. 537-546 (1967).

681 Stoeber, W., "Design and Performance of a Size-Separating Aerosol Centrifuge Facilitating Particle Size Spectrometry in the Submicron Range", Rochester Univ., New York, Clearinghouse No. UR-49-778 (1967).

682 Belz, R. A., "Analysis of the Techniques for Measuring Particle Size and Distribution from Fraunhofer Diffraction Pattersn", ARO, Inc., Clearinghouse No. AD 674 741 (Sep 1968).

683 Pollak, L. W., "Counting of Aitken Nuclei and Applications of the Counting Results", Int. J. Air Poll., V. 1, no. 4, p. 293-305 (Apr 1959).

684 Schutz, A., "Eine Anordnung zur Registrierenden Kontaktelektrischen Staubmessung", Staub-Reinhalt der Luft, V. 24, p. 359-363 (1964).

685 Parker, G. W., and Buchholz, H. "Size Classification of Submicron Particles by a Low-Pressure Cascade Impactor", Oak Ridge, Tenn., Clearinghouse No. ORNL-4226 (Jun 1968).

686 Beal, S. K., "Transport of Particles in Turbulent Flow to Channel or Pipe Walls", Bettis Atomic Power Lab., Pittsburgh, Pa., Clearinghouse No. WAPD-TM-765 (Apr 1968).

687 Bayer, J. L., Denton, G.H., and Hassel, R. E., "Use of the AMEDA Microscope in Quantitative Microscopy", American Society for Testing Materials, Spec. Tech. Publ. No. 430, p. 118-128 (1968).

688 Wohlers, H. C., Jackson, W. E., and Butmania, I., "A Rapid Emission Survey Procedure for Industrial Air Pollutants", APCA Journal, V. 19, no. 5, p. 309-314 (May 1969).

689 Rees, W. H., "Atmospheric Dirtiness", Inst. Heating & Ventilating Engineers Journal, V. 35, p. 243-252 (Nov 1967).

690 Saltzman, B. E., "Standardization of Methods for Measurement of Air Pollutants", APCA Journal, V. 18, no. 5, p. 326-328 (May 1968).

691 Diamant, W., "L' Investigation Optique Dans Recherche Concernant La Pollution Atmospherique", International Clean Air Congress Proc., V. 1, paper VII/a, London Eng., p. 237-238 (Oct 1966).

692 Anon, "Grit & Dust Emission from Solid Fuel Furnaces", Power & Works Eng., V. 61, no. 720, p. 21-25 (Jun 1966).

693 Schwarz, K., "Dust Emissions from Coal-Fired Boilers in the Federal Republic of Germany", International Clean Air Congress Proc., V. II, London, Eng., p. 136-141 (Oct 1966).

694 Sunavala, P. D. "Calculation of the Unburnt Carbon Loss in Coal-Fired Furnaces", Journal of Mines, Metals & Fuels, V. 16, no. 9, p. 333-334, (Sep 1968).

695 Rogers, L. H., "Relative Merits of Gas Chromatograph Colorimetry, and Spectrometry for Air Pollution Studies", American Society of Testing Materials, Spec. Tech. Publ. No. 250, p. 42-48 (1959).

696 Lipshtein, R. A., Blagova, T. A., Chuikova, T. A., Avetisyan, A. S., Kosobokova, E. M., and Korytnyi, E. F., "Reactions and Composition of Reaction Products from the Basic Components of Oil Fuel Ash", Thermal Eng., V. 15, no. 10, p. 79-82 (1968).

697 Wasser, J. H. Hangebrauck, R. P., and Schwartz, A. J., "Effects of Air Fuel Stoichiometry on Air Pollutant Emissions from Oil-Fired Test Furnance", APCA Journal, V. 18, no. 5 (p. 332-337 (may 1968).

698 Parrish, H. L, and Scholl, A. W., "Mass Spectrometric Analysis of Flue Gas", ISA - 8th Nat. Symposium on Instrumental Methods of Analysis Proc., 1962, p. 103-106.

699 Carey, W. F., "Atmospheric Deposits in Britain, A Study of Dinginess", Int. J. Air Poll., V. 2, p. 1-26 (1959).

700 Lucas, D. H., and Moore, D.J., "The Measurement in the Field of Pollution by Dust", Int. J. Air Wat. Poll., V. 8, p. 441-453 (1964).

701 Reba, I., "Combustion of Residual Fuel with Massive Recirculation", IIT Research Inst., Chicago, Ill., Clearinghouse No. PB 177 747 (1967).

702 Call, R. W., Palmer, E. P., and Grow, R. W., "Measurement of Atmospheric Aerosols by Polarized Laser Light Scattering", Utah University, Salt Lake City, Utah, Clearinghouse No. PB 175 688 (Jun 1967).

703 Abel, N. W., and Junge, C., "Studies of Size Distributions and Growth with Humidity of Natural Aerosol Particles", Max-Planck-Institute fur Chemie, Mainz, Germany, Clearinghouse No. AD 689 189 (Jan 1969).

704 Duerksen, K. D., Walker, R. L, and Karioris, R. G., "Exploding-Wire Aerosol Generator", Health Physics Division Annual Progress Report, K. Z. Morgan, et al, Oak Ridge National Laboratory, Oak Ridge, Tenn., Clearinghouse No. ORNL-4168, p. 296-298 (Oct 1967).

705 Jackson, M. R., Lieberman, A., Townsend, L. B., and Romanek, W., "Prototype Fly Ash Monitor for Municipal Incinerator Stacks", Proc. 1970 National Incinerator Conf., Cincinnati, Ohio, p. 182-188 (May 17-20 1970).

706 Pederson, P. D., Jr., "Microbiological Exploration of the Stratosphere", Litton Systems, Inc., Minneapolis, Minn., Clearinghouse No. N 68-28247, (Jun 1968).

707 Lewis, H. D., et al., "Theoretical Small-Particle Statistics: A Summary of Techniques for Data Analysis with Recent Developments in Data Comparison, Notation, and Mixture Theory", University of California, Los Alamos, N. M., Clearinghouse No. LA-3656 (Nov 1968).

708 Oblanas, J. W., and Collis, R. T. H., "Lidar Observations of the Pre-Gondola I Clouds", Stanford Research Institute, Menlo Park, Calif., Clearinghouse No. PNE 1110 (Jul 1967).

709 Major, W. S., "Solid Fuel Industry's Contribution to Air-Pollution Prevention", Proc. Smoke Prevention Assoc. of America, V. 42, p. 110-120 (1949).

710 Bush, A. F., "Instrumentation for Sampling and Analyzing Combustion Particulates Using an Electron Microscope", Proc. National Analytical Inst. Symp. 10th, San Francisco, Calif., p. 267-278 (1964).

711 Magill, P. L., "Instrument Measurement of Contamination in Clean Rooms for Proposed Federal Standard No. 209", Proc. National Analytical Inst. Symp., 10th, San Francisco, Calif., p. 287-297 (1964).

712 Leiberman, A., "Automatic and Remote Monitoring of Airborne Particles", Heating, Piping & Air Conditioning, v. 40, no. 11, p. 117-120 (Nov 1968).

713 Lee, G. K., Friedrich, F. D., and Mitchell, E. R., "Control of SO_3 in Low Presure Heating Boilers by an Additive", Journal Inst. of Fuel, V. 42, no. 337, p. 67-74 (Feb 1969).

714 Fiocco, G., and Grams, G., "Optical Radar Observations of Mesospheric Aerosols in Norway during Summer 1966", Journal of Geophysical Research, V. 74, no. 10, p. 2453-2458 (May 1969).

715 Weber, E., "Die Abtrennung von Feststoffteilchen aus Gasen durch Massenkrafte", Verfahrenstechnik, V. 3, no. 2, p. 51-58 (1969).

716 Anon, "Grit and Dust Sampling Equipment" Engineering & Boiler House Review, V. 75, no. 2, p. 51-53 (Feb 1960).

717 Fells, I., Howells, T.J., and Patrick, M.A., "Analysis of Fuel Gases and Combustion Products", Journal Inst. of Fuel, V. 34, p. 283-290 (Jul 1961).

718 Hurley, T. F., and Bailey, D. L. R., "The Correlation of Optical Density with the Concentration and Composition of the Smoke Emitted from a Lancashire Boiler", Journal Inst. of Fuel, V. 31, p. 534-550 (Dec 1958).

719 Badzioch, S., "Correction for Anisokinetic Sampling of Gasborne Dust Particles", Journal Inst. of Fuel, V. 33, p. 106-118, (Mar 1960.

720 Jackson, R., "The Measurement of Grit Emission", Steam Engineer, V. 28, p. 368-374 (Sep 1959).

721 Ounsted, D., and Schoen, J., "The Release of Sodium Aerosols During Combustion of Pulverized Coal: A Laboratory Investigation", Journal Inst. of Fuel, V. 33, no. 231, p. 199-206 (Apr 1960).

722 Williams, J., "Problems of Ambiguity Involved with the Utilization of of the Mie Theory in Particle Size Determination", Johns Hopkins Univ. Tech. Report No. 49, Clearinghouse No. AD 679 170 (Nov 1968).

723 Shifriu, K. S., and Raskin, V. F., "Theory of the Optical Method for Investigating Atmospheric Aerosols", Engl. Trans., from: Trudy Soveshchaniya Gid rometeoizdat, V. 9, p. 253-260, 1963, Clearinghouse No. AD 475 922 (Nov 1965).

724 Goldman, A., Lewis H. D., and Moore, R. H., "On the Proper Use of Transformations of Log Normal Functions in Small Particle Statistics", Univ. of California, Los Alamos, N.M., Clearinghouse No. LA 3262 (Dec 1964).

725 Tvorogov, S. D., "Calculation of Aerosol Optical Properties", Engl. Trans. from: Trudy Astrofizicheskogo Instituta Akademii Nauk Kazakhskoyssr, V. 3, p. 105-107, 1962, Clearinghouse No. AD 680 773 (Jan 1968).

726 Khmelevtsov, S. S. "A Size-Separation Collector for Sampling Aerosols from Curvilinear Flow", Eng. Trans. from: Trudy Astrofizicheskogo Instituta Akademii Nauk Kazakhskoyssr, V. 3, p. 108-114, 1962, Clearinghouse No. AD 678 123 (Nov 1967).

727 Vandergrift, A. E., "Particulate Pollutant System Study", Midwest Research Institute, Kansas City, Mo., Reports for NAPCA, U. S. Dept. of HEW, Cincinnati, Ohio, Cont. No. CPA 22-69-104 (1970).

728 Watts, J. L., "The Operation of Smoke Density Indicators", Engineering and Boiler House Rev., V. 82, p. 136-139 (1967).

729 Fuks, N. A., Stechkina, I. B., and Staroselsky, V. A., "Determination of Distribution of Aerosol Particles According to Size by Diffusion Method", Clearinghouse No. AI-Trans. -201 (1962).

730 Partridge, J. E., and Ettinger, H. J., "Calibration of a Spinning-Disc Aerosol Generator and Two-Stage Air Samplers", University of Calif., Los Alamos, N. M., Clearinghouse No. LA-4066 (Feb 1969).

731 Lewis, T. W., "Evaluation of an Automatic Aerosol Particle Counter for Measuring the Airborne Contamination Level in a Controlled Environment", George C. Marshall Space Flight Center, Huntsville, Ala., Clearinghouse No. 66 29075 (Mar 1966).

732 Burgess, W., and Reist, P. C., "Study of Space Cabin Atmospheres", Harvard School of Public Health, Clearinghouse No. N 67 12641, (Sep 1966).

733 Burgess, W., "Study of Space Cabin Atmospheres" Harvard School of Public Health, Clearinghouse No. N 66-23488 (Apr 1966).

734 Belyayev, S. P. "Accelerated Method of Measuring the Concentration of Natural Aerosols in a Solid Dispersion Phase with High Atmospheric Humidity", Gigiyena i Sanitariya, p. 64-67, Clearinghouse No. AD 674 487 (Jul 1968).

735 Lanzo, C. D., and Ragsdale, R. G., "Experimental Determination of Spectral and Total Transmissivities of Clouds of Small Particles", Lewis Research Center, Cleveland, Ohio, Clearinghouse No. N 62 16012 (Sep 1962).

736 Posner, S., Ettinger, H. J., Pratt, O. R., Jr., and Moore, R., "Evaluation of Particle Sizing Techniques: Comparison of Computer Particle Sizing Programs", Lovelace Foundation, Albuquerque, N. M., Clearinghouse No. LF 30, (Jul 1966).

737 Belz, R., A., "Analysis of the Techniques for Measuring Particle Size and Distribution from Fraunhofer Diffraction Patterns", ARO, Inc., Clearinghouse No. AD 674 741, AEDC-TR-68-125 (Sep 1968).

738 Smith, M., ed., "Recommended Guide for the Prediction of the Dispersion of Airborne Effluents" ASME, New York, N.Y. 85 p. (May 1968)

739 Cheng, L., and Soo, S. L., "Charging of Dust Particles by Impact", Journal of Applied Physics, V. 41, no. 2, p. 585-591 (1970).

740 Lepper, J. M., Jr., "Final Report for Study of Infrared Techniques for Monitoring Stack Gases", Dalmo Victor Co., Belmont, Calif., for Public Health Service, Washington, D. C., Cont. No. PH 86-65-61 (Oct 1965).

741 Goldman, A., Lewis, H. D., and Moore, R. H., "On the Proper Use of Transformations of Log Normal Functions in Small Particle Statistics", Clearinghouse No. LA-DC-6636 (Jul 1965).

742 Junge, C., "Mathematical Interrelationships in the Size Distribution of Atmospheric Aerosols Above the Continent", Engl. Trans: Bericht des Deutschen Wetterdienstes in der U. S. Zone Bad Kissingen, No. 35, p. 261-277, 1951, Clearinghouse No. N67-36177 (Jul 1967).

743 Deriagin, B., and Vlasenko, G., "The Flow Method of Ultramicroscope Measurement of the Particle Concentration of Aerosols in Other Dispersion Systems", Engl. Trans. from: Reports of the Academy of Sciences USSR, Physical Chemistry Section, V. 63, No. 2, p. 155-158, Clearinghouse No. AD 682 910 (Jan 1950).

744 Anon, Stack Emission Reports.

745 Reed, L. E., "The Estimation of the Darkness of Smoke by Visual Methods", Journal Inst. of Fuel, p. 3-9 (Jan 1959).

746 Lucas, D. H., "Certain Aspects of the Deposition of Dust", Journal Inst. of Fuel, p. 623-627 (Nov 1957).

747 Anon, "Methods for the Sampling and Analysis of Flue Gases - 3", British Standards Instn.,British Standard 1756, pt. 3, 36 p. (1965).

748 Anon, "Methods for Sampling and Analysis of Flue Gases - 4", British Standards Instn., British Standard 1756, pt. 4, 68 p. (1965).

749 McConnell, J. A., "Burner Fuel Oils Market Demand and Quality Requirements", Sun Oil Company, Marcus Hook, Penn., presented at National Fuels & Lubricants Meeting, New York, New York, Sept 11-12, 1968.

750 Stenger, R. L., Jr., "The Analysis of Coal Ash, Flyash, and Related Materials Using the Applied Research Laboratories Spectrographic Analyzer - Computer Assisted Data Reduction", Pittsburgh Conf. on Analytical Chemistry & Applied Spectroscopy, Cleveland, Ohio, March 1969, Report 44.

751 Bugden, A. R., Hamilton, R. J., and Jones, G. H.S., "Application of Photoelectric Densitometry to the Assessment of Respirable Dust Samples", British Journal of Applied Physics, V. 11, p. 371-377 (Aug 1960).

752 Harris, F. S., Jr., Sherman, G. C., and Morse, F. L., "Experimental Comparison of Scattering of Coherent and Incoherent Light", IEEE Trans. on Antennas and Propagation, V. AP-15, no. 1, p. 141-147 (Jan 1967).

753 Hamilton, R. J., and Walton, W. H., "The Selective Sampling of Respirable Dust", Mining Research Establishment, National Coal Board, England.

754 Musgrave, J. R., and Harner, H. R., "Turbimetric Particle Size Analysis", Eagle Picher Research Laboratories, Joplin, Mo., Research Technique & Technology, no. 1, 47 p. (1947).

755 Hartman, H. L., "Airborne Dust Determination and a New Method of Particle Sizing", Colorado School of Mines, Golden, Colo. (Nov 1956).

756 Martens, A. E., and Keller, J. D., "An Instrument for Sizing and Counting Airborne Particles", American Industrial Hygiene Assoc. Journal, V. 29, p. 257-267 (May - Jun 1968).

757 Dobbins, R. A., "An Emission-Scattering Photometer for Particle Size Measurement", Brown University, Providence, R. I., Report on research for Jet Propulsion Lab., Pasadena, Calif., Contract No. JPL 950573, (Aug 1964).

758 Collis, R. T. H., "Lidar", Science Journal, P. 72-77 (Feb 1968).

759 Dobbins, R. A., and Strand, L. D., "A Comparison of Two Methods of Measuring Particles Size of Al_2O_3 Produced by a Small Rocket Motor", Brown University, Providence, R.I.,

760 Anon,"Air Pollution Control - Basic Technology", Chemical Engineering, p. 165-172 (Apr 1970).

761 Maurin, P. G., and Jonakin, J., "Removing Sulfur Oxides from Stacks", Chemical Engineering, p. 173-180 (Apr 1970).

762 Squires, A. M., "Keeping Sulfur Out of the Stack", Chemical Engineering, p. 181-189 (Apr 1970).

763 Mills, J. L., "Continuous Monitoring", Chemical Engineering, p. 217-220 (Apr 1970).

764 Kotnick, G., and Scheck, H. F., "Monitoring SO_2 in Stacks", Instrumentation Technology, p. 52-55 (Sep 1969).

765 Holzhey, J., and Demmrich, H., "A Radio Metric Device for Continuous Control of Flue Dust Concentration", Neue Hutte, V. 14, no. 4, p. 198-201 (Apr 1969).

766 Ounsted, D., "A Rapid Multipoint, Oxygen Analyzer for Power Station Flue Gases", Journal Inst. of Fuel, p. 408-411 (Nov 1969).

767 Sumansky, L. W., "Gas Sampling Probe", U. S. Patent No. 2,459,047 (Aug 1969).

768 Bump, R. L., "The Use of Electrostatic Precipitators on Municipal Incinerators", Wheelabrator Corp., Mishawaka, Ind. 11 p.

769 Bricard, J., Deloncle, M., Pradel, J., and Madelaine, G., "Photoelectric Determination of Granular Size Distribution in an Aerosol", Staub-Reinhalt der Luft, V. 24, no. 8, p 387-290 (Aug 1964).

770 Sehmel, G. A., "Particle Deposition and Retention in Vertical Conduits", in: Hanford Radiological Sciences Research and Development Annual Report for 1964,,Pacific Northwest Laboratory, Richland, Wash., Clearinghouse No. BNWL-36 (Jan 1965).

771 Sehmel, G. A. and Schwendiman, L. C., "Particle Deposition Within a Curved Sampling Probe", in: Pacific Northwest Laboratory Annual Report for 1967 to USAEC Division of Biology and Medicine V. II: Physical Sciences - Part 3: Atmospheric Sciences, Battelle Memorial Inst., Richland,Wash.,Clearinghouse No. BNWL-715-Pt. 3, p. 88-91 (Oct 1968).

772 Mercer, T. T., Tillery, M. I., and Flores, M. A., "An Electostatic Precipitator for the Collection of Aerosol Samples for Particle Size Analysis", Lovelace Foundation, Albuquerque, N. M., Clearinghouse No. LF-7, Jul 1963).

773 Sehmel, G. A., and Schwendiman, L. C., "Particle Collection Efficiences on Wires", in: Pacific Northwest Laboratory Annual Report for 1967 to USAEC Division of Biology and Medicine - V. II: Physical Sciences - Part 3: Atmospheric Sciences, Battelle Memorial Inst., Richland, Wash., Clearinghouse No. BNWL-715, Pt. 3, p. 96-100 (Oct 1968).

774 Sehmel, G. A. "Validity of Air Samples as Affected by Anisokinetic Sampling and Deposition within the Sampling Line", Battelle Memorial Laboratory, Richland, Wash., Clearinghouse No. BNWL-SA-1045 (Apr 1967).

775 Sehmel, G. A., "Analysis of Particle Size Frequency Distributions" in: Hanford Radiological Sciences Research and Development Annual Report for 1964, Pacific Northwest Laboratory, Richland, Wash., Clearinghouse No. BNWL-36 (Jan 1965).

776 Gastwirth, J. L., "On Some Problems in the Theory of Particle Counting and the Infinitely Many Server Queue", Columbia Univ., Clearinghouse No. AD 407 819 (Mar 1963).

777 Sehmel, G. A. "Subisokinetic Sampling of Particles in an Air Stream", Pacific Northwest Laboratory, Richland, Wash., Clearinghouse No. BNWL-217 (Mar 1966).

778 Ettinger, H. J. and Posner, S., "Evaluation of Particle Sizing and Aerosol Sampling Techniques", University of Calif., Los Alamos, N. M., Clearinghouse No. LADC-5923 (Apr 1964).

779 Collins, J. T., Jr., Harris, W. J., Stromberg, D. D., and Power, J. L., "Airborne Particle Size Analysis, A composite Bibliography",U.S. Atomic Energy Comm., Clearinghouse No. IDO-12051 (May 1966).

780 Williams, J., "Determination of Particle Size and Concentration from Photometer and SECCHI Disc Measurements", The Johns Hopkins University, Clearinghouse No. AD 679 169 (Nov 1968).

781 Levine, B. S., "U.S.S.R. Literature on Air Pollution and Related Occupational Diseases - Vol. III", U. S. Public Health Service, Washington, D. C., Clearinghouse No. TT60-21475.

782 Honma, M., and Crosy, J., "A Symposium on Toxicity in the Close Ecological System", Lockheed Missiles & Space Co., Palo Alto, Calif., Clearinghouse No. PB 166 223.

783 Ferguson, J. S., Cope, R. T., and McFarren, E. F., "Air Particulates No. 1, Study Number 22", U. S. Dept. of Health, Education, and Welfare, Cincinnati, Ohio, Public Health Service Publication No. 999-AP-22 (1965).

784 Sherman, G. C., "Wavefront Reconstruction and Its Application to the Study of the Optical Properties of Atmospheric Aerosols", The Aerospace Corp., El Segundo, Calif., Clearinghouse No. N 69-38131 (Jul 1969).

785 Buchanan, L. M., Decker, H. M., Frisque, D. E., Phillips, C. R., and Dahlgren, C. M., "Novel Multi-Slit Large-Volume Air Sampler", Dept. of Army, Fort Detrick, Md., Clearinghouse No. AD 686 356 (1968).

786 Grigoryeva, L. V., "The Problem of Detection of a Virus Aerosol Under Experimental Conditions", Engl. Trans. from: Vop. Sanit. Bakt. Virus, p. 114-119, 1965, Clearinghouse No. AD 688 745 (Jun 1969).

787 Block, A. M., "Scattering of Laser Light by Uniform Spherical Particles", Rutgers State Univ., New Brunswick, N.J., Univ. Microfilms order no. 68-4527 (1967).

788 Anon, "Control Techniques for Particulate Air Pollutants", U. S. Public Health Service, Nat. Air Poll. Cont. Admin., Washington, D. C., U.S. Govt. Printing Office (1969).

789 Bullrich, K., Eiden, R., Eschelbach, G., Fischer, K., Hanel, G., Heger, K., Schollmayer, H., and Steinhorst, G., "Research on Atmospheric Optical Radiation Transmission", Institute for Meteorology, Mainz, Germany, Clearinghouse No. AD 690 114 (Jan 1969).

790 Ludwig, F. L., "Behavior of a Numerical Analog to a Cascade Impactor" Stanford Research Institute, Menlo Park, Calif., Clearinghouse No. AD 675 913 (Jul 1968).

791 Anon, "Microbiological Analyzing Methods for Aerosols", Dept. of the Army, Ft. Detrick, Frederick, Md., Clearinghouse No. AD 682 557 (Mar 1957).

792 Conner, W. D., and Hodkinson, J. R., "Optical Properties and Visual Effects of Smoke-Stack Plumes", National Center for Air Pollution Control, Cincinnati, Ohio, Clearinghouse No. PB 174 705 (1967).

793 Yajnik, M., Witeczek, J., and Heller, W., "Electronic Computations of Light Scattering Functions for Heterodisperse Systems of Isotropic Spheres", Wayne State University, Detroit, Mich., Clearinghouse No. AD 654 724 (Jul 1967).

794 Mason, R., Ryan, P., and Hill, S. L., "Filter Pack Technique for Classifying Radioactive Aerosols by Particle Size, Part IV", Naval Research Lab., Washington, D. C., Clearinghouse No. AD 621 565 (Aug 1965).

795 Barrett, R. E., Moody, J. W., Hazard, H. R., Putnam, A. A., and Locklin, D. W., "Residual Fuel Oil-Water Emulsions", Battelle Memorial Institute, Columbus, Ohio, Clearinghouse No. PB 189 076 (1970).

796 Saunders, A. W., Jr., Patterson, R. L., Jr., and Lockhart, L. B., Jr., "Standardization of Beta Counting Procedures Used at NRL in the Radiochemical Analysis of Air Filter Samples", Naval Research Lab., Washington, D. C., Clearinghouse No. AD 653 448 (May 1967).

797 Anon, "Air Quality Criteria for Particulate Matter", National Air Pollution Control Admin., Raleigh, N. C., AP-49 (Jan 1969).

798 Melnik, W. L., and Weske, J. R., "Advances in Hot-Wire Anemometry", Maryland University, College Park, Md., Clearinghouse No. AD 676 019 (Jul 1968).

799 Burgess, W. A., and Reist, P. C. "Study of Space Cabin Atmospheres", Harvard School of Public Health, Clearinghouse No. N68-28606 (1968).

800 Fesenkov, B. G., ed., "Scattering and Polarization of Light in the Atmosphere", Engl. Trans. from: Trudy Astrofizicheskogo Instituta Akademiya Nauk Kazakhskoi SSR, V. 3, 1964, Clearinghouse No. TT 65-50005 (1965).

801 Sehmel, G. A., and Schwendiman, L. C., "The Effect of Sampling Probe Diameter on Sampling Accuracy", in: Pacific Northwest Laboratory Annual Report for 1967 to USAEC Division of Biology and Medicine - V. II: Physical Sciences - Pt. 3: Atmospheric Sciences, Battelle Memorial Inst., Richland, Wash., Clearinghouse No. BNWL-715, Pt. 3, p. 92-95 (Oct 1968).

802 Landry, M. J., "GB-60A Light Detecting and Ranging System (LIDAR)", Sandia Laboratories, Albuquerque, N. M., Clearinghouse No. SC-DR-67-115 (Dec 1967).

803 Anon, "Questions of Atmospheric Diffusion and Air Pollution (Selected Articles", Engl. Trans. from Leningrad, Main Geophysical Observatory, Transactions, No. 172, p. 23-24, 42-47, 74-78, (1965)., Clearinghouse No. AD 668 053 (1967).

804 Heller, W., Tabibian, R., Nakagaki, M., and Papazian, L., "Flow Light Scattering" Wayne State University, Detroit, Michigan, Clearinghouse No. AD 694 522 (Jul 1969).

805 McCormick, M. P., and Lawrence, J. D., Jr., "Tables of Mie Scattering Functions for Particles with Refractive Index 1.5", Langley Research Center, Langley Station, Hampton, Va., Clearinghouse No. N 69-20905, NASA TN D-5110 (Mar 1969).

806 Chu, B., and Schoenes, F. J., "The Laser Homodyne "Self-Beating Technique in Light Scattering", University of Kansas, Lawrence, Kansas, Clearinghouse No. AD 693 948 (1968).

807 Anon, "Remote Controlled Sequential Sampler Developed by Dugway Proving Ground",Dugway Proving Ground, Dugway, Utah, Clearinghouse No. AD 695 628 (May 1969).

808 Burton, J. S., "Infrared Spectroscopic Study of Gas-Solid Interactions", General Technologies Corp., Reston, Va., Clearinghouse No. PB 182 988 (Jan 1969).

809 Freedman, R. W., Lang, H. W., and Jacobson, M., "Gas Chromatographic Analyses of the PrincipalConstituents of Mine Atmospheres", Bureau of Mines, Washington, D. C., Clearinghouse No. PB 183 373 (Sep 1968).

810 Lang, H. W., O'Neill, W. E., Coulehan, B. A., and Freedman, R. W., "Continuous Monitoring of Diesel Exhaust Gas for Carbon Dioxide, Carbon Monoxide, Oxygen, Methane, and Nitrogen Oxides", Bureau of Mines, Wash., D.C., Publication RI 7241, Clearinghouse No. PB 183 386 (Mar 1969).

811 Ukeguchi, N., Sakata, H., Okamoto, H., and Ide, Y., "Study on Stack Gas Diffusion", Mitsubishi Heavy Industries Ltd., Japan, Clearinghouse No. PB 186 259 (Aug 1967).

812 Johnson, W. B., Jr., and Uthe, E. E., "Lidar Study of Stack Plumes", Stanford Research Institute, Menlo Park, Calif., Clearinghouse No. PB 185 893 (Jun 1968).

813 Dunn, J. F., Jr., Foster, A. R., Lautman, D. A., Nardone, L. J., Swanson, J. L., and Zelinski, J. J., "On the Design of an Instrument to Use Forward-Scattered Light to Detect Small Particles", Northeastern Univ., Boston, Mass., Clearinghouse No. AD 693 557 (Aug 1969).

814 Grinnel, S. W., Webster, F., and Brown, T. S., "Studies of the Performance of the Rotorod FP Sampler" Metronics Assoc., Inc., Palo Alto, Calif., Clearinghouse No. AD 692 320 (Jun 1965).

815 Klahr, C. N., Cutler, S. N., and Kalikstein, K., "Application of Dust for Space Structures", Fundamental Methods Associates, Inc., New York, N.Y., Clearinghouse No. N 68-32976, NASA Cr-1136 (Aug 1968).

816 Anon, "An Economic Feasibility Study of Coal Desulfurization Vol. I", Paul Weir Co., Inc., Chicago, Ill., Clearinghouse No. PB 176 845 (Oct 1965).

817 McCartney, J. T., O'Donnell, H.J., and Sabri, E., "Pyrite Size Distribution and Coal-Pyrite Particle Association in Steam Coals", Bureau of Mines, Publication RI 7231, Clearinghouse No. PB 183 380 (Feb 1969).

818 Brown, P. M., and Hochrainer, D., "Conical Aerosol Spectrometer, Cylindrical Aerosol Spectrometer", National Center for Atmospheric Research, Boulder, Colorado, Clearinghouse No. PB 180 880.

819 Lepper, J. M., Jr., "For Study of Infrared Techniques for Monitoring Stack Gases", Dalmo Victor Corp., Belmont, Calif., Clearinghouse No. PB 187 391 (Oct 1965).

820 Lepper, J. M., Jr., "Passive IR SO_2 Sensor", Dalmo Victor Corp., Belmont, Calif., Clearinghouse No. PB 187 390 (Oct 1967).

821 Romanek, W., Jackson, M. R., and Lieberman, A., "Prototype Fly Ash Monitor for Incinerator Stacks", ITT Research Inst., Chicago, Ill., Clearinghouse No. PB 187 393 (Sep 1968).

822 Jacobi, W., Eichlers, J., and Stolterfoht, N., "Particle Size Spectrometry of Aerosols Through Light Scattering in a Laser Beam", Sandia Lab., Albuquerque, N. M., Clearinghouse No. PB 187 705T (Nov 1969).

823 Freitag, J. A. "Comparison of Methods for Particle Size Analysis", National Lead Co. of Ohio, Cincinnati, Ohio, Clearinghouse No. NCLO-925 (Sep 1964).

824 Neitzel, W. E., "A High-Volume, Real-Time Aerosol Monitor", Sandia Lab., Albuquerque, N. M., Clearinghouse No. SC-DR-69-56 (Jun 1969).

825 Meyer, C. T., "A Method for Determining the Particle Size of Airborne Dust", Monsanto Research Corp., Mound Lab., Miamisburg, Ohio, Clearinghouse No. MLM-1596 (Jun 1969).

826 Hidalgo, J.U., "Study of the Application of Laser Technology to Atmospheric Contamination Measuration", Tulane Univ., Clearinghouse No. N69-36282, NASA CR 86221 (Apr 1969).

827 Anon, "Laboratory Contaminant Sensor Development, Final Report", Perkin-Elmer, Clearinghouse No. N 69 37578 (Jul 1969).

828 Vaerman, J., "Problems of Soot Emission and Low Temperature Corrosion in Domestic Oil-Fired Biolers", The Inst. Petroleum, V. 50, p. 155-168 (Jul 1964).

829 Badzioch, S., "Collection of Gas Borne Dust Particles by Means of Aspirated Sampling Nozzle", British Journal of Applied Physics, V. 10, p. 26-32 (Jan 1959).

830 Vonnegut, B., and Neubauer, R., "Detection and Measurement of Aerosol Particles", Analytical Chemistry, V. 24, no. 6, p. 1000-1013 (1952).

831 Hemeon, W. C. L., "Instruments for Air Pollution Measurement", Meteorological Monographs, V. 1, no. 4, p. 20-23 (Nov 1951).

832 Jarrett, B. A., and Heywood, H., "A Comparison of Methods for Particle Size Analysis", British Journal of Applied Physics, Sup. no. 3, p S21-S28 (1954).

833 Heywood, H., "Fundamental Principles of Sub-Sieve Particle-Size Measurement", paper presented at Inst. of Mining & Metallurgy Symp. on Mineral Dressing, London, Eng., Paper No. 6 (Sep 23-25, 1952).

834 Higgins, R. I., and Dewell, P., "The Measurement of Airborne Dust Concentration in Iron-Foundries Using the Hexlet Dust Sampler, B.C.I.R.A. Journal, V. 8, no. 3, p. 425-436 (May 1960).

835 Heywood, H., "The Scope of Particle Size Analysis and Standardization", Symposium on Particle Size Analysis, p. 1-11 (1947).

836 Hodkinson, J. R., "Some Observations on Light Extinction by Spherical Particles", British Journal of Applied Physics, V. 14, p. 931-932 (Dec 1963).

837 Hurd, F. K., and Mullins, J. C., "Aerosol Size Distribution from Ion Mobility", Journal of Colloid Science, V. 17, no. 2, p. 91-100 (Feb 1962).

838 Hosey, A. D., and Jones, H. H., "Portable Electrostatic Precipitator Operating from 110 Volts A. C. or 6 Volts D. C.", A.M.A. Archieves of Industrial Hygiene and Occupational Medicine, V. 7, p. 49-57 (Jan 1953).

839 Katz, J., and Verrochi, W. A., "A Filter Test Method for the Rapid Weight Distribution of Dust in Gas Streams for the Evaluation of Dust Collectors", Pennsylvania Electric Co., Johnstown, Pa., Paper #67-117 presented at the APCA Annual Meeting, Cleveland, Ohio (Jun 11-16 1967).

840 Knudson, H. W., and White, L., "Development of Smoke Penetration Meters", U. S. Naval Research Laboratory, Washington, D. C., NRL Report P-2642 (1945).

841 Willis, E., Kerker, M., and Matijevic, E., "Effect of Brownian Coagulation Upon Light Scattering of Colloidal Dispersions of Narrow Size Distribution", *Journal of Colloid & Interface Science*, V. 23, (1967).

842 Kratohvil, J. P., and Smart, C., "Calibration of Light-Scattering Instruments, III. Absolute Angular Intensity Measurements on Mie Scatterers", *Journal of Colloid Science*, V. 20, no. 8, p. 875-892 (1965).

843 Kratohvil, J. P., "Light Scattering", *Analytical Chemistry*, V. 36, no. 5, p. 458R-472R (Apr 1964).

844 Kratohvil, J. P., "Light Scattering", *Analytical Chemistry*, V. 38, p. 517R-526R (Apr 1966).

845 Smart, C., Jacobsen, R., Kerker, M., Kratohvil, J. P., and Matijevic, E., "Experimental Study of Multiple Light Scattering", *Journal of the Optical Society of America*, V. 55, no. 8, p. 947-955 (Aug 1965).

846 Penndorf, R. B., "Total Mie Scattering Coefficients for Spherical Particles of Refractive Index n=2", *Journal of the Optical Society of America*, V. 46, p. 1001 (Nov 1956).

847 Penndorf, R. B., "Total Mie Scattering Coefficient for Spherical Particles of Refractive Index n=1", *Journal of the Optical Society of America*, V. 47, no. 7, p. 603-605 (Jul 1957).

848 Penndorf, R. B., "New Tables of Total Mie Scattering Coefficients for Spherical Particles of Real Refractive Indexes (1.33<n<1.5)", *Journal of the Optical Society of America*, V. 47, no. 11 p. 1010-1015 (Nov 1957).

849 Littlewood, A., "Measurement of the Optical Density of Smoke in a Chimney", *Journal of Scientific Instruments*, V. 33, p. 495-499 (Dec 1956).

850 Lambie, R., "Improved Smoke Density Recorder", *Journal of Scientific Instruments*, V. 37, p. 144-146 (Apr 1960).

851 Collins, K. E., and Steele, D. J., "High-Sensitivity Recording Optical Density Meter", *Journal of Scientific Instruments*, V. 38, p. 186-190 (May 1961).

852 Herman, B. M., "Infra-red Absorption, Scattering, and Total Attenuation Cross-Sections for Water Spheres", *Royal Meteorological Society, Quarterly Journal*, V. 88, p. 143-150 (1962).

853 Gumprecht, R. S., and Sliepcevich, C. M., "Tables of Light-Scattering Functions for Spherical Particles", University of Michigan Press (1951).

854 Haas, J. C., "Determination of the Density of Fly Ash Suspensions", MS Thesis, Dept. of Mech.,Eng., University of Ill., (1968).

855 Tate, B. E., "Properties of Coal - Their Influence on Performance of Coal-Burning Apparatus", ASME Paper 52-SA-56, 11 p. (1952).

856 Miller, C. E. "Preventing Air Pollution from Coal-Fired Steam Generators", ASME Paper 52-SA-68, 14 p. (1952).

857 Grohse, E. S., "Atmospheric Pollution: the Role Played by Combustion Processes", APCA Journal, V. 8, no. 3, p. 255-266 (Nov 1958).

858 Jarvis, W. D., "The Selection and Use of Additives in Oil-Fired Boilers", Journal Inst. of Fuel, V. 31, no. 214, p. 480-491 (Nov 1958).

859 Anon, "Instruments for the Study of Atmospheric Pollution", ASME Committee on Air Pollution Controls, New York, 3rd Ed., 23 p. (1959).

860 Alexander, N. E., "How to Find Fine Particles", Air Engineering, V. 1, no. 4, p. 43-46, 48 (Jul 1959).

861 Hawksley, P. G., "Discussion on Improved Sampling Equipment for Solids in Flue Gases", Journal Inst. of Fuel, V. 32, p. 112-119 (Mar 1959).

862 Mauss, F., and Djavanmard, H., "Cobalt-Base Additives Reduce Soot Emission by Oil-Burning Equipment", Cobalt, no. 11, p. 21-27 (Jun 1961).

863 Kanter, C. V., Lunche, R. G., and Fudurich, A. P., "Techniques of Testing for Air Contaminants from Combustion Sources, APCA Journal, V. 6, no. 4, p. 191-199 (1957).

864 Flood, L. P., "Soot and Odor Problems from Burning Residual Fuel Oil", APCA Proc., V. 49, Paper No. 38, 11 p. (1956).

865 Nader, J. S., "A Versatile, High Flowrate Tape Sampler", APCA Journal, V. 9, no. 1, pl 59-61 (1959).

866 Roberts, L. R., and McKee, H. C., "Evaluation of Absorption Sampling Devices", APCA Journal, V. 9, no. 1, p. 51-53 (May 1959).

867 Jacobs, M. B., Braverman, M. M., and Hochheiser, S., "Continuous Determination of Carbon Monoxide and Hydrocarbons in Air by a Modified Infrared Analyzer", APCA Journal, V. 9, no. 2, p. 110-114 (Aug 1959).

868 Whiteley, A. B., and Reed, L. E., "The Effect of Probe Shape on the Accuracy of Sampling Flue Gases for Dust Content", Journal Inst. of Fuel, V. 32, p. 316-320 (Jul 1959).

869 Romanovsky, J., Taylor, J. R., MacPhee,R. D., and Dickinson, J. E. "Air Monitoring of the Los Angeles Atmosphere with Automatic Instruments", APCA Proc., V. 49, 23 p. (1956).

870 Marble, F. E., "Dynamics of a Gas Containing Small Solid Particles", Proc. 5th AGARD Combustion Propulsion Coloq., p. 175-215 (1963).

871 Sullivan, J. L., "The Calibration of Smoke Density", APCA Journal, V. 12, no. 10, p. 474-478 (Oct 1962).

872 Schutz, A., "Report on the Clean Air Maintenance Exhibition, 5-9th Apr 1965, Dusseldorf", Staub-Reinhalt der Luft (Engl. Trans.), V. 25, no. 11, p. 77-90 (1965).

873 Luckert, J., "Conference Reports, 1. On Aerosol Mechanics, 29th-30th Oct 1964, Mainz", Staub-Reinhalt der Luft (Engl. Trans.), V. 25, p. 28-32 (1965).

874 Horn, W., "Process for Continuous Gravimetric Determination of the Concentration of Dustlike Emissions", Staub-Reinhalt der Luft (Engl. Trans.), V. 28, p. 20-25 (1968).

875 Eisenbud, M., and Petrow, H. G., "Radioactivity in the Atmospheric Effluents of Power Plants that use Fossil Fuels", Science, V. 144, p. 288-289 (Apr 1964).

876 Knollenberg, R. G., "An Optical-Electrical Particle Size Discriminator", University Corp. for Atmospheric Research, Clearinghouse No. PB 179 645 (Apr 1968).

877 Anon, "Electron Microprobe X-Ray Analysis of Atmospheric Aerosol Particles", Advanced Metals Research Corp., Burlington, Mass., Clearinghouse No. PB 189 283 (1969).

878 Pustinger, J. V., Jr., Hodgson, F. N., Strobel, J. E., and Evers, R. L., "Identification of Volatile Contaminants of Space Cabin Materials", Monsanto Res. Corp., Dayton, Ohio, Clearinghouse No. AD 700 061 (Oct 1969).

879 Mohnen, V., "Investigation of the Attachment of Neutral and Electrically Charged Emanation Decay Products to Aerosols", Thesis, Ludwig-Maximilians-Universitat, Munich, Clearinghouse No. AERE-Trans.-1106 (1966).

880 Cavanagh, L. A., "Development of Instrumentation for Airborne Collection of Atmospheric Organic Chemicals", Stanford Research Inst., Menlo Park, Calif., Clearinghouse No. N68-36675 (Sep 1968).

881 Whatley, M. E., Haas, P. A., Horton, R. W., Ryon, A. D., Suddath, J.C., and Watson, C. D., "Unit Operations Monthly Progress Report, Oct 1964, Chemical Technology Division", Oak Ridge National Laboratory, Oak Ridge, Tenn., Clearinghouse No. ORNL-TM-1069 (May 1965).

882 Ettinger, H. J., and Royer, G. W., "Calibration of a Two-Stage Air Sampler", Univer. of Calif., Los Alamos, N.M., Clearinghouse No. LA-4234 (1969).

883 Anon, "Applying NASA Technology to Air Pollution: The Sulfur Dioxide Problem", Wayne State Univ., Detroit, Mich., Clearinghouse No. N69-39189 (1969).

884 Wojan, C. A., Buono, D. F., and Reichman, J. M., "Experimental Investigation of the Settling of Particles in Laminar Flow in Horizontal Tubing", Polytechnic Inst. of Brooklyn, Brooklyn N. Y., Clearinghouse No. TID-24285 (Jan 1968).

885 Langer, G., "Electrostatic Classification of Submicron Airborne Particles", IIT Research Insti., Chicago, Ill., Clearinghouse No. ARF-3187-8 (1962).

886 Wilson, D. L., "Recent Advances in Coulter Counter Particle Size Analysis", National Lead Co. of Ohio, Cincinnati, Ohio Clearinghouse No. NLCO-893 (Sep 1963).

887 Bourquin, K. R., and Shigemto, F. H., "Investigation of Air-Flow Velocity by Laser Backscatter", Ames Research Center, Moffett Field, Calif., Clearinghouse No. NASA-TN-D-4453 (Apr 1968).

888 Sanderson, H. P., and Katz, M., "The Optical Evaluation of Smoke or Particulate Matter Collected on Filter Paper", APCA Journal, V. 13, no. 10, p. 476-482 (Oct 1963).

889 Glenn, R. A., and Harris, R. D., "Liberation of Pyrite From Steam Coals", APCA Journal, V. 12, p. 388-395, 404 (Aug 1962).

890 Billings, C. E., and Silverman, L., "Aerosol Sampling for Electron Microscopy", APCA Journal, V.12, p. 586-590 (Dec 1962).

891 Householder, M. K., and Goldschmidt, V. W., "The Impaction of Spherical Particles on Cylindrical Collectors", Journal of Colloid & Interface Science, V. 31, no. 4, p. 464-478 (Dec 1969).

892 Matthews, B. A., and Rhodes, C. T., "Some Observations on the Use of the Coulter Counter Model B in Coagulation Studies", Journal of Colloid & Interface Science, V. 32, no. 2, p. 339-348 (Feb 1970).

893 Rimberg, D., and Thomas, J. W., "Comparison of Particle Size of Latex Aerosols by Optical and Gravity Settling Methods", Journal of Colloid & Interface Science, V. 32, no. 1, p. 101-105 (Jan 1970).

894 Goetz, A., "A New Instrument for the Evaluation of Environmental Aerocolloids", *Environmental Science & Technology*, V. 3, no. 2, p.154-160 (Feb 1969).

895 Orr, C., Jr., "Automatic Particle Size Analysis in the Subsieve Range", Paper 6-1, U.S. -Japan Particulate Technology Seminar, Kyoto, Japan (6-11 Oct 1969).

896 Tanaka, T., and Nakajima, Y., "Continuous On-Line Particle-Size Analyzer", Paper 6-2 U.S. - Japan Particulate Technology Seminar, Kyoto, Japan, (6-11 Oct 1969).

897 Jimbo, G., Yamazaki, M., Asaka, S., Fujita, S., and Ishii, Y., "A Proposal for the Measuring Method of Particle Size and Shape by Photo-scanning Image Analyzing", Paper 6-3, U.S. - Japan Particulate Technology Seminar, Kyoto, Japan (6-11 Oct 1969).

898 Kanagawa, A., "Sideways Light Scattering Particle Counter", Paper 6-6, U.S. - Japan Particulate Technology Seminar, Kyoto, Japan (6-11 Oct 1969).

899 Yuu, S., and Iinoya, K., "A New Weighing Type Cascade Impactor", Paper 6-7, U.S.-Japan Particulate Technology Seminar, Kyoto, Japan (6-11 Oct 1969).

900 Iinoya, K., and Tanaka, Z., "Particle Size Classification by Deposition Angle in a Reduced Pressure Centrifuge", Paper 8-7, U.S.-Japan Particulate Technology Seminar, Kyoto, Japan (6-11 Oct 1969).

901 Iinoya, K., and Watanabe, K., "A New Type of Powder Flow Meter", Paper 9-10, U.S.-Japan Particulate Technology Seminar, Kyoto, Japan (6-11 Oct 1969).

902 Szantho, E. V., "Agglomeration of Dust in Smoke Flues", *Staub-Reinhalt der Luft (Engl. Trans.)*, V. 29, no. 8, p. 6-9 (Aug 1969).

903 Ruping, G., "The Importance of Ioskinetic Suction in Dust Flow Measurement by Means of Sampling Probes", *Staub-Reinhalt det Luft (Engl. Trans.)*, V. 28, no. 4, p. 1-11 (Apr 1968).

904 Stober, W., "The Problem of Aerosol Centrifuge Properties", *Staub-Reinhalt der Luft (Engl. Trans.)*, V. 29, no. 5, p. 12-15 (May 1969).

905 Hilbig, G., "Particle Size Distribution of Polydisperse Systems by Means of the First Maximum Method", *Staub-Reinhalt der Luft (Engl. Trans.)*, V. 29, no. 5, p. 1-5 (May 1969).

906 Pueschel, R. F., and Rossano, A. T., "Light Extinction by Mixed Aerosol Systems", Paper presented at 59th Annual Meeting, APCA, San Francisco, Calif. (Jun 20-24 1966).

907 Reif, A. D., White, C. S., and Giblin, M. E., "Aerosol Production and Size Analysis with the Roller Separator", A.M.A. Archieves of Industrial Health, V. 14, p. 442-449 (Nov 1956).

908 Renninger, F. A., "A Monitoring System for the Detection and Control of Airborne Dust", Dust Topics Magazine, (Oct 1966).

909 Sinclair, D. and LaMer, V. K., "Light Scattering as a Measure of Particle Size in Aerosols", Chemical Reviews, V. 44, p. 245-267 (1949).

910 Wilcox, J. D., and Van Antwerp, W. R., "A Sampling Technique for Small Air-Borne Particulates", A.M.A. Archieves of Industrial Health, V.11, p. 422-424 (May 1955).

911 Anon, Particle Analyzer System.

912 Walton, W. H., "Theory of Size Classification of Airborne Dust Clouds by Elutriation", British Journal of Applied Physics, Supp. no. 3, p. S29-S39 (1954).

913 Whitby, K. T., "Size Measurement of Particles", Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.

914 Whitby, K. T., "Small Particle Statistics", Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.

915 Zimmer, C. E., and Fair, D. H., "An Evaluation of Suspended Particulate Measurements", presented at Annual Meeting, APCA, Chicago, Illinois (May 21-24, 1962).

916 Vonnegut, B., Moore, C. B., Ehrenfeld, J., and Smallman, C. R., "Determining the Concentration of Fogs and Other Aerosols by A Space-Charge Measuring Instrument", Artificial Stimulation of Rain, Proc. Conf. Phys. Cloud Precipitation Particles, 1st Woods Hold Conf., 1955 (Pub. 1957).

917 Feifel, E., "Laufende Uberwachung des Staubgehalts von Gasen Mittels registrierender Gerate", Staub-Reinhalt der Luft, V. 19, no. 5, p. 139-143 (May 1959).

918 Noll, K. E., Mueller, P. K., and Imada, M., "Visibility and Aerosol Concentration in Urban Air", Atmospheric Environment, V. 2, p. 465-475 (1968).

919 Charlson, R. J., Ahlquist, N. C., Horvath, H., "On the Generality of Correlation of Atmospheric Aerosol Mass Concentration and Light Scatter", Atmospheric Environment, V. 2, p. 455-464 (1968).

920 Spurny, K. R., and Lodge, J. P., Jr., "Radioactivity Labeled Aerosols", Atmospheric Environment, V. 2, p. 429-440 (1968).

921 Schmidt, K. G., "A New Dust-Measuring Instrument with a Panel Unit Preseparator and an Air Flow Rate of 12 M^3/Hr.", Staub-Reinhalt der Luft (Engl. Trans.), V. 26, no. 5, p. 7-12 (May 1966).

922 Schutz, A., "A Recording Dust-Measuring Instrument Based on Electric Contact, with Legarithmic Indication", Staub-Reinhalt der Luft (Engl. Trans.), V. 26, no. 5, p. 18-21 (May 1966).

923 Prochazka, R., "Recording Dust Measurement With the Konitest", Staub-Reinhalt der Luft (Engl. Trans.), V. 26, no. 5, p. 22-28 (May 1966).

924 Stober, W., and Flachsbart, H., "Aerosol Size Spectrometry with a Ring Slit Conifuge", Environmental Science & Technology, V. 3, no. 7, p. 641-651 (Jul 1969).

925 Stober, W., and Flachsbart, H., "Size-Separating Precipitation of Aerosols in a Spinning Spiral Duct", Environmental Science & Technology, V. 3, no. 12, p. 1280-1296 (Dec 1969).

926 Frankel, R. J., "Problems of Meeting Multiple Air Quality Objectives for Coal-Fired Utility Boilers", Journal APCA, V. 19, no. 1, p. 18-23 (Jan 1969).

927 Rodes, C. E., Palmer, H. F., Elfers, L. A., and Norris, C.H., "Performance Characteristics of Instrumental Methods for Monitoring Sulfur Dioxide", APCA Journal, V. 19, no. 8, p. 575-584 (Aug 1969).

928 Charlson, R. J., Ahlquist, N. C., Selvidge, H., and MacCready, P. B., Jr., "Monitoring of Atmospheric Aerosols Parameters with the Integrating Nephelometer", APCA Journal, V. 19, no. 12, p. 937-942 (Dec 1969).

929 Horvath, H., and Rossano, A. T., Jr., "Technique for Measuring Dust Collector Efficiency as a Function of Particle Size", APCA Journal, V. 20, no. 4, p. 244-246 (Apr 1970).

930 Romine, J. O., and Gayle, J. B., "Evaluating the HIAC PC-101 Automatic Particle Counter",AACC Journal, (Jan 1964).

931 Anon, "Specification Sheet for the HIAC Automatic Particle Counter", High Accuracy Products Corp., Claremont, Calif., Bulletin 6303.

932 Wood, R. C., McFarland, A. R., Olson, R.K., and Upton, J. E., "Air Ejector Particle Sampler, A Progress Report", Litton Systems Inc., Minneapolis, Minn., for Div. of Biology and Medicine, U.S. Atomic Energy Comm., Cont. no. AT(11-1)-401 (Sep 1964).

933 Rossano, A. T., Jr., Masaki, H., and Pueschel, R. F., "Influence of Aerosol Characteristics on Visibility", Univ. of Washington, Seattle, Wash., for: U.S. Public Health Service, Cont. no. DAP/RTGB-AP0336 (May 1966).

934 Steigerwald, B. J., and Lynn, D. A., "Air Ions as an Index of Air Pollution", Case Institute of Tech., Cleveland, Ohio, for: U.S. Public Health Service, Cont. no. PH 86-62-34, (Sep 1962).

935 Johnson, J. C., Eldridge, R. G., and Terrell, J. R., "An Improved Infrared Transmissometer for Cloud Drop Sizing",Mass.Inst. of Technology, Cambridge, Mass., Clearinghouse No. AD 47 794 (Jul 1954).

936 Fernandez, G., "Particle Size Determination by Use of Electrostatic Precipitation Patterns and Radioactive Tracers", Air Force Institute of Tech., Wright-Patterson Air Force Base, Ohio (Aug 1964).

937 Ortman, G. C., "A Photometric Pressure Sensor", paper presented at Annual Meeting, APCA, New York, N.Y., Reprint Paper 61-4 (Jun 1961).

938 Aronson, M. H., and Peterson, A. H., "A New Recording Microbalance", *Instruments & Automation*, (Jul 1955).

939 Burson, J. H., Iinoya, K., and Orr, C., Jr., "Particle Size Classifier for the Subseive Range", *Review of Scientific Instruments*, V. 34, no. 9, p. 1023-1025 (Sep 1963).

940 Burson, J. J., Iinoya, K., Orr, C., Jr., "Particle Size Classification by Adhesion", *Nature*, V. 200, no. 4904, p. 360-361 (Oct 1963).

941 Anon, "Comparison Methods for Particle Size Analysis", in: *Summary Technical Report for the Period October 1, 1962 to December 31, 1962*, National Lead Co., Cincinnati, Ohio, Clearinghouse No. NLCO-865, p. 43-51 (Feb 1963).

942 Snyder, A. D., and Wooten, G. W., "Feasibility Study for the Development of a Multifunctional Emission Detector for NO,CO, and SO_2", Monsanto Research Corp., Dayton, Ohio, Clearinghouse No. PB 188 103 (Oct 1969).

943 Anon, "Applications of Ultrasonic Energy, Ultrasonic Instrumentation for Nuclear Applications", Aeroprojects, Inc., West Chester, Pa., Clearinghouse No. NYO-9585 (Oct 1961).

944 Grune, W. N.,Burrows, H., and Orr, C., Jr., "Effects of High Density Ionizing Radiation on Colloidal Systems and Suspensions", Georgia Inst. of Technology, Atlanta, Ga., Clearinghouse No. TID-16694 (Jun 1962).

945 Ligda, M. H., "Detection of Cement Dust Clouds with a Pulsed Ruby Lidar", Stanford Research Inst., Menlo Park, Calif., Clearinghouse No. UCRL-13204 (Mar 1966).

946 Smith, W. S., and Gruber, C. W., "Atmospheric Emissions from Coal Combustion - An Inventory Guide", U. S. Public Health Service, Division of Air Pollution, Cincinnati, Ohio, Clearinghouse No. PB 170 851 (Apr 1966).

947 Juda, J., and Budzinski, K., "Atmospheric Pollution", Trans. by: Joint Publications Research Service, Washington, D. C., from Polish book: Zanieczyszczenis Atmosfery, Wydawn ictwa Naukowo-Techniczne, Warsaw, 256 p, 1961, Clearinghouse No. JPRS 18455 (Mar 1963).

948 Mercer, T. T., "The Stage Constants of Cascade Impactors", Lovelace Foundation, Albuquerque, N. M., Clearinghouse No. LF-12 (Oct 1963).

949 Whitfield, W. J., and Mashburn, J. C., "Development of an Increased Sampling Rate Monitoring System", Sandia Lab., Albuquerque, N.M., Clearinghouse No. SC-RR-66-585 (Oct 1966).

950 Littlewood, A., "Measurement of the Optical Density of Smoke in a Chimney", Journal of Scientific Instruments, V. 33, p. 495-499 (Dec 1956).

951 Heinrich, D. O., "Study on Electro-Precipitator Performance in Relation to Particle Size Distribution, Level of Collection Efficiency and Power Input", Trans. Institute of Chemical Engineers, V. 39, p. 145-163 (Apr 1961).

952 Gucker, F. T., Jr., O'Konski, C. T., "Electronic Methods of Counting Aerosol Particles", Chemical Reviews, V. 44, no. 2, p. 373-388 (1949).

953 Gillespie, T., and Langstroth, G.O., "An Instrument for Determining the Electric Charge Distribution in Aerosols", Canadian Journal of Chemistry, V., 29, no. 11, p. 1056-1068 (1951).

954 Gillespie, T., and Gunter, A. W., "The Drag on Spheres and Cylinders in a Stream of Dust-Laden Air", Journal of Applied Mech., Ser. E., V. 26, no. 4, p. 584-586 (Dec 1959).

955 Dennis, R., Samples, W. R., Anderson, D. M., and Silverman, L., "Isokinetic Sampling Probes", Industrial & Engineering Chemistry, V. 49, no. 2, p. 294-302 (Feb 1957).

956 Cohen, J., and Dickinson, R. W., "The Measurement of the Resistivity of Power Station Flue Dust", Journal of Scientific Instruments, V. 40, p. 72-75 (Feb 1963).

957 Brink, J. A., Jr., "Cascade Impactor for Adiabatic Measurement", Industrial & Eng. Chemistry, V. 50, no. 4, p. 645-648 (Apr 1958).

958 Blacktin, S. C., "Instrument for Both Counting and Weighing Particles of Dusts, Smokes, and Other Dispersions", Journal Society of Chemical Industry, V. 56, p. 281-283T (1937).

959 Bayles, A. L., "Effects of Particle Size on Firing Pulverized Solid Fuels in Boilers", Mechanical Engineering, V. 80, p. 111 (Mar 1958).

960 Whitby, K. T., Algren, A. B., and Jordan, R. C., "Size Distribution and Concentration of Air-Borne Dust", Heating, Piping & Air Conditioning, V. 27, no. 8, p. 121-128 (Aug 1955).

961 Van Den Akker, J. A., Hardacker, K. W., and Dearth, L. R., "Instrumentation Studies - LXXIX - Beta-Ray Gages", Tappi, V. 40, no. 5, p. 179A-211A (May 1957).

962 Tolman, R. C., and Reyerson, L. H., Brooks, A. P., and Smyth, H. D., "An Electrical Precipitator for Analyzing Smokes", Journal American Chemical Society, V. 41, p. 587-589 (1919).

963 Storey, R. M., "Smoke Density Integrator", Journal of Applied Physics, V. 11, p. 509-512 (Nov 1960).

964 Stoecker, W. F., "Smoke-Density Measurement. Correlation of Solids Content in Gas with Photoelectric Smoke-Meter Readings", Mechanical Engineering, V. 72, no. 10, p. 793-798 (1950).

965 Slater, C., and Cohen, L., "A Centrifugal Particle Size Analyzer", Journal of Scientific Instruments, V. 39, p. 614-617 (Dec 1962).

966 Rounds, G. L., and Matoi, H. J., "Electostatic Sampler for Dust-Laden Gases", Analytical Chemistry, V. 27, p. 829-830 (May 1955).

967 Rendle, L. K., and Wilsdon, R. D., "The Prevention of Acid Condensation in Oil-Fired Boilers", Combustion, V. 29, p. 39-48 (Jul 1957).

968 Mazumdar, B. K., Choudhury, S. S., and Lahiri, A., "Alicyclicity and Smoke Emission of Coal", Nature, V. 183, p. 1613 (Jun 1959).

969 Nader, J. S., Ortman, G. C., and Massey, M. T., "Light-Scatter Instrumentation for Measurement of Atmospheric Particulates", American Industrial Hygiene Assn. Journal, V. 22, no. 1, p. 42-48 (Feb 1961).

970 Nader, J. S., and Allen, D. R., "A Mass Loading and Radio Activity Analzyer for Atmospheric Particulates", 52nd Annual Meeting, APCA, Los Angeles, Calif., Paper No. 59-28 (Jun 1959).

971 Schweyer, H. E., and Work, L. T., "Methods for Determining Particle Size Distributions", American Society for Testing Materials, V. 41, p. 1-22 (1941).

972 White, H. J., "Effect of Fly Ash Characteristics on Collector Performance", Annual Meeting American Society of Mechanical Engineers, Paper No. 54-A-259 (Nov 28 - Dec 3 1954).

973 Traxler, R. N., and Baum, L. A. H., "Measurement of Particle Size Distribution by Optical Methods", American Society for Testing Materials, V. 35, p. 457-470 (1935).

974 Metnieks, A.L., "On the Various Methods of Deducing Aerosol Size Distribution from Diffusional Decay Measurements", Pure & Applied Physics, V. 61, p. 183-190 (1965).

975 McCormick, R. A., and Baulch, D. M., "The Variation with Height of the Dust Loading over a City as Determined from the Atmospheric Turbidity", APCA Journal, V. 12, no. 10, p. 492-496 (Oct 1962).

976 Lipscomb, W. N., Rubin, T. R., and Sturdivant, J. H., "An Investigation of a Method for the Analysis of Smokes According to Particle Size", Journal of Applied Physics, V. 18, no. 1, p. 72-79 (Jan 1947).

977 Nolan, P. J., and Scott, J. A., "The Influence of Variations in Pressure and Temperature on the Calibration of a Photoelectric Nucleus Counter", Proc. Royal Irish Academy, V. 64, Sec. A., No. 3, P. 37-48 (1964).

978 Van der Hulst, H. C., Light Scattering by Small Particles, Wiley, New York (1957).

979 Rose, H. E., The Measurements of Particle Size in Very Fine Powders, Constable, London (1953).

980 Morgan, B. B., and Meyer, E. W., "Multi-Channel Photoelectric Scanning Instrument for Sizing Microscopic Particles", Journal of Scientific Instruments, V. 36, p. 492-501 (Dec 1959).

981 Nolan, P. J., and Scott, J. A., "The Exhaustion Method of Nucleus Size Analysis", Proc. Royal Irish Academy, V. 65, Sec. A., no. 2, p. 13-25 (1966).

982 Langer, G., Radnik, J., and Templeton, L, "Development of Simple, High-Resolution Mobility Analyzer for Small, Charged Particles", Armour Research Foundation, Ill. Inst. of Tech., Chicago, Ill. (1961).

983 Langer, G., Radnik, J., and Templeton, L., "Development of a Simple, High-Resolution Mobility Analyzer for Small, Charged Particles", Review of Scientific Instruments, V. 33, no. 1, p. 83-84 (Jan 1962).

984 Kratohvil, J. P., "Calibration of Light-Scattering Instruments, IV. Corrections for Reflection Effects", Journal of Colloid & Interface Science, V. 21, no. 5, p. 498-512 (May 1966).

985 Gee, S., "Method for Laser Measurement of Particle Concentration in Gases", Air Force Systems Command, Arnold Air Force Base, Tenn., DDC No. AEDC-TR-67-44 (Feb 1967).

986 Blacktin, S. C., "Range of Electrotor Meter Demonstrated by Dark Field Count", Journal of Industrial Hygiene and Toxicology, V. 19, p. 579-589 (1937).

987 Cartwright, J., Nagelschmidt, G., and Skidmore, J. W., "The Study of Air Pollution with the Electron Microscope", Quarterly Journal of Royal Meteol. Soc., V. 82, p. 82-86 (Jan 1956).

988 Channell, J. K., and Hanna, R.J., "Experience with Light Scattering Particle Counters",Archives of Environmental Health, V. 6, p. 92-106 (1963).

989 Guruswamy, S., and Narasimhachar, V. S., "Geometric Mean Particle Size & Its Application in the Sampling of Airborne Dust", Journal of Sci. Ind. Research (New Delhi), V. 18B, p. 319-323 (Aug 1959).

990 Harley, J. H., "Sampling and Measurement of Airborne Daughter Products of Radon", Nucleonics, V. 11, no. 7, p. 12-15 (Jul 1953).

991 Nader, J. S., Hagee, G. R., and Setter, L. R., "Evaluating the Performance of the Internal Counter", Nucleonics, V. 12, no. 6, p. 29-31 (Jun 1954).

992 Blacktin, S. C., "The Electrotor Dust and Smoke Meter", Journal of Industrial Hygiene and Toxicology, V. 18, no. 9, p. 583-594 (1936).

993 Hosey, A. D., Jones, H. H., and Ayer, H. E., "Evaluation of an Aerosol Photometer for Dust Counting and Sizing", American Industrial Hygiene Assoc. Journal, V. 21, p. 491-501 (Dec 1960).

994 Schulz, E. J., Duffee, R. A., Mitchell, R. I., and Ungar, E. W., "A Tracer Technique to Measure Deposition of Stack Emissions", American Industrial Hygiene Assoc. Journal, V. 21, p. 343-349 (Oct 1960).

995 Mercer, T. T., "The Interpretation of Cascade Impactor Data", American Industrial Hygiene Assoc. Journal, V. 26, p. 236-241 (May-Jun 1965).

996 Hounam, R. F., and Sherwood, R. J., "The Cascade Centripeter: A Device for Determining the Concentration and Size Distribution of Aerosols", American Industrial Hygiene Assoc. Journal, V. 26, p. 122-131 (Mar-Apr 1965).

997 Dimmick, R. L., "A Light-Scatter Probe for Aerosol Studies", American Industrial Hygiene Assoc. Journal, V.22, p. 80-81 (Feb 1961).

998 Donoso, J. J., "An Improved Automatic Smoke Sampler", American Institute of Mining and Metallurgical Engineers Journal of Metals, V. 188, p. 610-612 (1950).

999 Wasser, R. W., "Sampling Effluent Gases for Particulate Matter", American Industrial Hygiene Assoc. Journal, V. 19, p. 469-476 (Dec 1958).

1000 Stephan, D. G., Bohnslav, P. T., Herrick, R. A., Walsch, G. W., and Rose, A. H., Jr., "A New Technique for Fabric Filter Evaluation", American Industrial Hygiene Assoc. Journal, V. 19, p. 276-284 (1958).

1001 Mercer, T. T., Mills, C. M., and Gibb, A. R., "Collection Efficiencies of a Cascade Filtration Device Employing Wire Gauzes", Ann. Occupational Hygiene, V. 1, p. 301-313 (Apr 1960).

1002 Lippmann, M., "Review of Cascade Impactors for Particle Size Analysis and a New Calibration for the Casella Cascade Impactor", American Industrial Hygiene Assoc. Journal, V. 20, p. 406-416 (Oct 1959).

1003 Gaines, A. F., and Pitt, G.J., Smokeless Fuels from High-Volatile Coals. II. The Smoke Emission of Low-Temperature Chars Prepared from High-Volatile Coals", Int. J. Air Poll., V. 1, p. 266-275 (Apr 1959).

1004 Guyton, A. C. "Electronic Counting and Size Determination of Particles in Aerosols", Journal of Industrial Hygiene and Toxicology, V. 28, p. 133-141 (1946).

1005 Gregory, D. H., and Adams, W.N., "Smokeless Fuels from High-Volatile Coals. I. The Production of Smokeless Fuels by the Mild Devolatilization of a High-Volatile Coal", International Journal of Air Pollution, V. 1, p. 263-265 (Apr 1959).

1006 Toynbee, P. A., and Parkes, W. J. S., "Isokinetic Sampler for Dust-Laden Gases", Int. J. Air Wat. Poll., V. 6, p. 113-120 (Mar-Apr 1962).

1007 Dimmick, R. L., Hatch, M. T., and Ng, J., "A Particle-Sizing Method for Aerosols and Fine Powders", A.M.A. Archives of Industrial Hygiene & Health, V. 18, p. 23-29 (Jul 1958).

1008 Wilcox, J. D., and Van Antwerp, W. R., "A Sampling Technique for Small Air-Borne Particulates", AMA Archives of Industrial Health, v. 422-424 (May 1955).

1009 Spurny, K., and Hampl, V., "Preparation of Radioactively Labelled Condensation Aerosols. I. Aerosols of Sodium Chloride, Silver Iodide and Sulphuric Acid", Coll. Czech. Chem. Commun., V. 30, p. 507-515 (1965).

1010 Narjes, I., "Dust Sampler Equipment for Quasi-Isokinetic Sampling by Means of Novel Zero-Pressure Probes", Chem. Age India, V. 19, no. 8, p. 595-603 (Aug 1968).

1011 Denzel, P., and Horn, W., "Ein Empfindliches Messverfahren zur Kontinuierlichen Bestimmung der Gravimetrischen Konzentration von Staubformigen Emissionen", ETZ-A, V. 87, p. 311-312 (1966).

1012 Kayse, J. R., "Air Pollution Problems from High Temperature Stacks", American Industrial Hygiene Assoc. Quart., V. 18, no. 3, p. 246-252 (Sep 1957).

1013 Myers, M. N., "Literature Survey: Sampling, Plate-Out and Cleaning of Gas-Cooled Reactor Effluents", General Electric Co., Cincinnati, Ohio, Clearinghouse No. TID 14469 (1961).

1014 Burgess, W. A., and Reist, P. C., "Semiannual Progress Report, Study of Space Cabin Atmospheres, Harvard School of Public Health, Boston, Mass., Clearinghouse No. N69-10455 (Oct 1968).

1015 Essick, M. L., "Literature Search on Methods of Particle Size Measurement", Rohm and Hass Co., Huntsville, Ala., Clearinghouse No. AD 483 867 (Jun 1966).

1016 Muller, H., "The Sensitivity and Accuracy of Thickness Measurement with Radioactive Nuclides by the Transmissivity Method", Instruments and Measurements, Proc., 5th Int. Instrum. and Measurem. Conf., 13-16 Sep 1960, Stockholm, Sweden, V. 2., Academic Press, N.Y., p. 733-745 (1961).

1017 Lieberman, A., and Schipman, P. "Air-Pollution Monitoring Instrumentation", IIT Research Institute, Chicago, Ill., Clearinghouse No. NASA SP-5072 (1969).

1018 Brink, J. A., Jr., and Porthouse, J.D., "Efficient Dust Control Via New Sampling Technique", Chemical Engineering, V. 76, no. 5, p. 106-110 (Mar 1969).

1019 White, H. J., "Effect of Fly-Ash Characteristics on Collector Performance", APCA Journal, V. 5, p. 37-50 (May 1955).

1020 Flodin, C. R., and Haaland, H. H., "Some Factors Affecting Fly-Ash Collector Performance on Large Pulverized Fuel-Fired Boilers", APCA Journal, V. 5, p. 27-32 (May 1955).

1021 Jones, W. I., and Owen,J., "Smokeless Fuel from Low-Rank Coals Carbonized in a Fluidized Bed", Journal Inst. of Fuel, V. 35, p. 404-417 (Sep 1962).

1022 Chojnowski, B., "A Multipoint Solid and Gas Sampling Probe", Journal Inst. of Fuel, V. 37, p. 79-81 (Feb 1964).

1023 Bailey, D. L. R., and Reed, L. E., "The Reduction of Smoke From a Vertical Boiler Fired by an Underfeed Stoker", Journal Inst. of Fuel, V. 33, p. 188-192 (Apr 1960).

1024 Ashman, R., "The Problems of Corrosion, Blockage, and Smut Emission from Combustion Processes", Steam Engineer, V. 30, p. 255-259 (May 1961).

1025 Lees, B., and Morley, M. C., "A Routine Sampler for Detecting Variations in the Emission of Dust and Grit", Journal Inst. of Fuel, V. 33, p. 90-95 (Feb 1960).

1026 Marsen, D., and Mott, R. A., "Oxides of Sulfur in the Flue Gases of a Coke-Fired Domestic Boiler", Journal Inst. of Fuel, V. 33, p. 267-270 (Jun 1960).

1027 Byers, R., L., "Particle Deposition from Turbulent Stream by Means of Thermal Force", Ph.D. Thesis, Penn State Univ. (1967).

1028 Tillery, M. I., "Design and Calibration of a Modified Conifuge", Lovelace Foundation, Albuquerque, N. M., Clearinghouse No. LF-34 (Jan 1967).

1029 Gast, T. H., "Determination of Solids in Hot Waster Gases Using Electrical Micro-Balance", Chemie-Ingenieur-Technik, V. 29, p. 262-266 (Apr 1957).

1030 Anon, "Guide for Respirable Mass Sampling", American Industrial Hygiene Assoc. Journal, p. 133-137 (Mar-Apr 1970).

1031 Beck, M. S., and Wainwright, N., "Current Industrial Methods of Solids Flow Detection and Measurement", Powder Technology, V. 2, p. 189-197 (1968).

1032 Martin, R., "Generator Can Double as Anti-Pollution Weapon", Petr/Chem. Engr., V. 38, no. 9, p. 52, 55-56 (1966).

1033 Hicks, C. E., "Sensor Measures Stack Effluents--Accurately", Petro/Chem. Engr., V. 39, no. 5, p. 33-34 (1967).

1034 Alpern, B., Courbon, P., Plateau, J., and Tissandier, G., "Microscopic Examination of Samples Taken from a Pulverized-Fuel Flame", Journal Inst. of Fuel, V. 33, no. 235, p. 399-405 (1960).

1035 Dorman, R. G., "Dust Sampling", Filtration & Separation, V. 5, no. 6, p. 549-558 (Nov-Dec 1968).

1036 Schutz, A., "An Arrangement for Continuous Recording Dust Measurements by the Contact-Electrification Method", Staub-Reinhalt der Luft, V. 24, no. 9, p. 359-363 (Sep 1964).

1037 Landwehr, M., "Experience of the Use in Gravimetric Dust Measuring Instruments of Preliminary Separators for Dust Particles", Staub-Reinhalt der Luft, V. 24, no. 8, p. 329-332 (Aug 1964).

1038 Baum, F., and Riess, F. "An Automatic Dust Sampler Based on the Membrane Filter Principle", *Staub-Reinhalt der Luft*, V. 24, no. 9, p. 369-370 (Sep 1964).

1039 Stuke, J., and Rzeznik, J., "The Tyndallograph, A Photo electric Dust-Measuring Instrument", *Staub-Reinhalt der Luft*, V. 24, no. 9, p. 366-368 (Sep 1964).

1040 Coenen, W., "Dust Measurement and Recording by the Method of Small Ion Accumulation", *Staub-Reinhalt der Luft*, V. 24, no. 9, p. 350-353 (Sep 1964).

1041 Prince, L. H., and Kwolek, W. F., "Coincidence Corrections for Particle Size Determinations with the Coulter Counter", *Rev. of Scientific Instruments*, V. 36, no. 5, p. 646-653 (May 1965).

1042 Robin, M. A., and Spektorskii, V. N., "Method of Determining Soot Content in Hot Gas Flows", *Industrial Lab., USSR (Engl. Trans.)*, V. 35, no. 2, p. 248-249 (Feb 1969).

1043 Morrow, P. E., and Mercer, T. T., "A Point-to-Plane Electostatic Precipitator for Particle Size Sampling", *American Industrial Hygiene Assoc. Journal*, V. 25, p. 8-14 (Jan-Feb 1964).

1044 Landstrom, D. K., and Kohler, D., "Electron Microprobe Analysis of Atmospheric Aerososl", Battelle Memorial Institute, Columbus, Ohio, Clearinghouse No. PB 189 282 (Dec 1969).

1045 Doyle, A. W., Lilienfeld, P., McCoy, J. F., Sherman, C., Morganstern, P., Hommel, C. O., Driscoll, J. N., and Sacco, A. M., "Aerosol Dissemination Assessment, Second Annual Report", GCA Corp., Bedford, Mass., Clearinghouse No. AD 826 726 (Jan 1968).

1046 Goldschmidt, V., "The Sampling of Aerosols in a Turbulent Air Flow", Syracuse University, Clearinghouse No. AD 258 962 (May 1961).

1047 Vonnegut, B., Doyle, A. W., and Sliney, P. M., "Research in Electrical Phenomena Associated with Aerosols", Arthur D. Little, Inc., Clearinghouse No. AD 260 746 (Jul 1961).

1048 Lilienfeld, P., "Aerosol Dissemination Assessment, Ninth Quart. Progress Report", GCA Corp., Bedford, Mass., Clearinghouse No. AD 832 787 (Dec 1967).

1049 Lilienfeld, P., "Aerosol Dissemination Assessment, 10th Quart. Progress Report", GCA Corp., Bedford, Mass., Clearinghouse No. AD 832 788, (Mar 1968).

1050 Grandjean, J., Sneyers, R., and Levert, C., "Resultats de la Comparaison Internationale des Instruments de Mesure de la Radioactive Artificielle Beta des Poussieres de l Air", Organisse Par l'Institut Royal Meteorologique de Belgique, Brussells, Belgium, Clearinghouse No. N 70-17217 (1967).

1051 Barnes, T. M., Hoffman, A. O., and Lownie, H.W., Jr., "Evaluation of Process Alternatives to Improve Control of Air Pollution from Production of Coke", Battelle Memorial Institute, Columbus, Ohio, Clearinghouse No. PB 189 266 (Jan 1970).

1052 Ettinger, H. J., "Survey of Techniques Employed to Define Aerosol Respirable Dust Concentration and Particle Size Characteristics", University of Calif., Los Alamos, N. M., Clearinghouse No. LA-4249.

1053 Sarkisov, S. L., Stepanov, G. V., and Shvedow, S. V., "The Character of Solid Aerosol Sedimentation in Impact Collectors", Engl. Trans. from: Nalchik, Vysokogornyy Geofizicheskiy Institut, Trudy, No. 8, p. 9-12,1968, Clearinghouse No. AD 703 568 (1968).

1054 Skopp, A., Sears, J. T., and Bertrand, R. R., "Fluid Bed Studies of the Limestone Based Flue Gas Desulfurization Process", ESSO Research & Engineering Co., Linden, New Jersey, Clearinghouse No. PB 189 495 (Aug 1969).

1055 Duprey, R.L., "Compilation of Air Pollutant Emission Factors", Public Health Service, Raleigh, N. C., Clearinghouse No. PB 190 245 (1968).

1056 Anon, "Radioassay Procedures for Environmental Samples", U. S. Public Health Service, Washington, D. C., Clearinghouse No. PB 189 357 (Jan 1967).

1057 Lippmann, M., "Respirable Dust Sampling", *American Industrial Hygiene Assoc. Journal*, V. 31, p. 138-159 (1970).

1058 Kubitschek, H. E., "Electronic Measurement of Particle Size", *Research*, (London), V. 13, p. 128-135 (Apr 1960).

1059 Morgan, B. B., "Automatic Particle Counting and Sizing", *Research*, V. 10, p. 271-279 (Jul 1957).

1060 Groutsch, E. R., "Automatic Dust Sampler", *Australasian Institute of Mining and Metallurgy Proc.*, No. 191, p. 165-189 (Sep 1959).

1061 Izmailov, G. A., "Measuring the Gravimetric Concentration of Dust in the Air using β-Radiation", *Zavodskaya Laboratoriya*, V. 27, no. 1, p. 40-43 (1961). English translation in: *Industrial Laboratory*.

1062 Jackson, R., and Granville, R. A., "Measurement of Dust in Flue Gases", Proc. Air Pollution Meeting, Sep 25-26, 1957, and Proc. Water Pollution Meeting, Dec. 11-21, 1957, London, *Air and Water Pollution in the Iron & Steel Industry* (1958).

1063 Kalishevskii, L. L., and Ganchev, B. G., "A Study of the Cyclone Process When Burning Solid Fuel", *Thermal Engineering*, USSR, no. 2, p. 70-74 (Feb 1967).

1064 Tebbens, B. D., Thomas, J. F., and Mukai,M., "Particulate Air Pollutants Resulting from Combustion", *ASTM Sp. Tech. Pub. 352, Symp. on Air Pollution Methods* (1963).

1065 Lilienfeld, P., "Aerosol Dissemination Assessment, 11th Quarterly Progress Report", GCA Corp., Bedford, Mass., Clearinghouse No. AD 833 701 (May 1968).

1066 Kiktenko, V. S., Safronov, Y. P., Kudryautsev, S.I., Fedorov, B. F., Pushchin, N. I., and Fedorovich, A. A., "Photoelectric Count of the Number of Aerosol Particles of Organic and Inorganic Origin", Engl. Trans. from: *Gigiyenai Sanitariay, Moscow*, V. 26, no. 2, p. 47-53, Feb. 1961, Clearinghouse No. JPRS-8334 (May 1961).

1067 Barth, W., Nagel, R., and Waveren, K., "New Method for the Instantaneous Determination of Material Quantities Moved in Air Stream of Pneumatic Conveyers", *Chemie-Ing. Techn.*, V. 29, no. 9, p. 599-602 (1957).

1068 Renshaw, F. M., Bachman, J. M., and Pierce, J. O., "The Use of Midget Impingers and Membrane Filters for Determining Particle Counts", *American Industrial Hygiene Assoc. Journal*, V. 30, no. 2, p. 113-116 (Mar-Apr 1969).

1069 Ramanujam, M., and Venkateswarlus, D., "Particle-Size Analysis", *Chemical Age of India*, V. 19, no. 11, p. 975-983 (1968).

1070 Ramsden, A. R., "A Microscopic Investigation into the Formation of Fly-Ash During the Combustion of a Pulverized Bituminous Coal", *Fuel*, V. 48, no. 2, p. 121-137 (Apr 1969).

1071 Salo, E. A., "Visible Exhaust From Fuel Oils", *Hydrocarbon Process*, V. 49, no. 2, p. 96-98 (Feb 1970).

1072 Huang, C. M., Kerker, M., Matijevic, E., and Cooke, D. D., "Aerosol Studies by Light Scattering, VII, Preparation and Particle Size Distribution of Linolenic Acid Aerosols", *Journal of Colloid and Interface Science*, V. 33, no. 2, p. 244-254 (Jun 1970),

1073 Lauer, O., "Application of a New Type of Precision Micro-Sieve to Particle-Size Determination", *Staub-Reinhalt der Luft*, V. 20, no. 3, Clearinghouse No. 62-10270 (Mar 1960).

1074 Schmidt, K. G., "Phase Contrast Microscopy in Dust Technology", Staub-Reinhalt der Luft, p. 436-367, Clearinghouse No. 59 14631 (1955).

1075 Dennis, R., and Gordon, D., "Aerosol Dissemination Assessment", 3rd Quart. Prog. Report, GCA Corp., Bedford, Mass., Clearinghouse No. AD 803 989 (Oct 1966).

1076 Kanter, C. V., Lunche, R. G., and Fudurich, A. P., "Techniques for Testing for Air Contaminants from Combustion Sources", Pres. at 49th Annual Meeting, APCA, Buffalo, New York, (May 1956).

1077 Severyanin, V. S., "The Combustion of Solid Fuel in a Pulsating Flow", Thermal Engineering, USSR, V. 16, no. 1, p. 9-13 (1969).

1078 Ivanov, K. I., Zeger, K. E., and Chmovzh, V. E., "Preventing Fouling of Oil-Fired Boiler Heating Surfaces by Using Additives", Thermal Engineering, USSR, V. 16, no. 1, p. 22-27 (1969).

1079 Vetter, H., "Comparative Long-Duration Trials of Dust Concentration Recording Instruments in the Flue Gases of Brown Coal-Fired Power Plants", Vereiningung der Grosskesselbesitzer - Mitteilungen, V. 49, no. 1, p. 23-27 (Feb 1969).

1080 Charlson, R. J., Ahlquist, N. C., Selvidge, H., and MacCready, P. B., Jr., "Monitoring of Atmospheric Aerosol Parameters with the Integrating Nephelometer", APCA 62nd Annual Meeting, Paper 69-91 (Jun 1969).

1081 Sholtes, R. S., "Behavior of Aerosol Particles in a Thermal Gradient", Ph.D. Thesis, Univ. of Florida, 131 p.(1961).

1082 Knollenberg, R. G., "The Optical Array: An Alternative to Scattering or Extinction for Airborne Particle Size Determination", Journal of Applied Meteorology, V. 9, no. 1, p. 86-103 (Feb 1970).

1083 Kogan, Y. I., and Pankratova, M. E., "Dependence of Light Scattering on Particle Size in Aerosol Nephelometers with Viewing Angles of 90 and 135 Deg.", Colloid Journal,USSR (Engl. Trans.), V. 31, no. 4, p. 496-500 (Jul-Aug 1969).

1084 Bianconi, W. D., "Rapid Method for Evaluating Dust Collectors", Occupational Health Review, V. 22, (1967).

1085 Dresia, H., "The Determination of the Ash-Content of Coal with Beta and Gamma Rays", Brennstoff-Chemie, V. 43, no. 5, p. 149-152 (May 1962).

1086 Luxl, F. C., "Sampling, Analyzing and Control of Oxygen in Boiler Flue Gas", Preprint, Am. Soc. of Mechanical Eng., N.Y., 8 p. 1961 (Pres. at Am. Soc. of Mech. Eng. Winter Annual Meeting, N.Y., Nov 26 - Dec 1 1961).

1087 Walters, D. F., and Martin, D. O., "An Evaluation of the Air Pollution Aspects of the Proposed Steam-Electric Plant at Oak Park, Minnesota", U. S. Public Health Service, Air Poll. Div., Cincinnati, Ohio (Feb 1965).

1088 Mayer, M. "A Compilation of Air Pollutant Emission Factors for Combustion Processes, Gasoline Evaporation, and Selected Industrial Processes", U. S. Public Health Service, Air Poll. Div., Cincinnati, Ohio (May 1965).

1089-a Anon, "Conference on Liquid Borne Particle Metrology, Feb. 1-2, 1968, New York, N.Y.", in: Annals. New York Academy of Sciences, V. 187, Art. 3 (Jun 1969).

1089-b Barnett, M., "Double Image Microscopy for Size-Analysis Techniques", Paper presented at Conference on Liquid Borne Particle Metrology, Feb. 1-2, 1968, New York, N.Y., in: Annals. New York Academy of Sciences, V. 187, Art. 3 (Jun 1969).

1089-c Martens, A. "Light Scattering by Microscopic Particles", Paper Presented at the Conference on Liquid-Borne Particle Metrology, Feb. 1-2, 1968, New York, N.Y., in: Annals. New York Academy of Sciences, V. 187, Art. 3

1089-d Carver, L., "Light Blockage by Particles as a Measurement Tool", Paper Presented at the Conference on Liquid-Borne Particle Metrology, Feb. 1-2, 1968, New York, N.Y., in: Annals. New York Academy of Sciences, V. 187, Art. 3, (Jun 1969).

1089-e Weersing, J., "Light Scattering Measurements for Counting and Sizing Particles", Paper Presented at the Conference on Liquid-Borne Particle Metrology, Feb.1-2, 1968, New York, N.Y., in: Annals. New York Academy of Sciences, V. 158, Art. 3, (Jun 1969).

1089-f Zinky, W. R., "Hologram Techniques for Particle Size Analysis", Paper Presented at the Conference on Liquid-Borne Particle Metrology, Feb. 1-2, New York, N.Y., in: Annals. New York Academy of Sciences, V. 158, Art. 3, (June 1969).

1090 Mauk, C. E., Mock, T. C., and Staffin, R., "Study and Preliminary Design of a Real Time Chemical Simulant Sampler", Houston Research Inst., Houston, Texas, Clearinghouse No. AD 868 348 (Sep 1967).

1091 Gutterman, B., "Dust Properties in Relation to Dust Collection", Dissertation Abstracts, V. 19, p. 2892 (May 1959).

1092 "Restricting Emission of Dust from Manually Operated General-Heating Boilers, Capacity 600,000 KCal/hr. and Less, Fired with Solid Fuels", VDI No. 2115, (Jun 1961).

1093 Hart, H., "Zur Problematik der Ermittlung des okonomischen Nutzens beim technischen Einsatz von Kernstrahlung", Isotopentechnik, V. 12, p. 373-380 (1962).

1094 Jech, C., "Die Ausnutzung des Alpha-Ruckstrasses zur Untersuchung der Eindringtiefe radioaktiver Aerosole in Filterschichten", *Staub-Reinhalt der Luft*, V. 20, p. 75-76 (1960).

1095 Dennis, R., and Hommel, C. O., "Aerosols Dissemination Assessment, 2nd Quarterly Report", GCA Corp., Bedford, Mass., Clearinghouse No. AD 481 953 (May 1966).

1096 Mauer, F. A., "An Analytical Balance for Recording Rapid Changes in Weight", *The Review of Scientific Instruments*, V. 25, p. 598-602 (1954).

1097 Caule, E.J., and McCully, G., "An Automatic Recording Analytical Balance", *Canadian Journal of Technology*, V. 33, p. 1 (1955).

1098 Mercer, T. T., "On the Calibration of Cascade Impactors", *Ann. Occupational Hygiene*, V. 6, no. 1, p. 1-14 (1963).

1099 Dennis, R., Euling, R., Gussman, R. A., and Hommel, C. O., "Aerosol Dissemination Assessment, First Quarterly Progress Report", GCA Corp., Bedford, Mass., Clearinghouse No. AD 476 243 (Dec 1965).

1100 Leonard, J. W., and Humphreys, K. K., "Coal Research in West Virginia Since 1961", West Virginia Univ., Morgantown, W. Va., Coal Research Bureau Report No. 52 (1969).

1101 Fairbanks, H. V. "Acoustic Drying of Ultrafine Coal", West Virginia Univ, Morgantown, W. Va., Coal Research Bureau Report No. 51 (1969).

1102 Wilson, E. B., and Cockrell, C. F., "Application of Evolutionary Operation to the Heavy Media Cleaning of Coal", West Virginia Univ., Morgantown, West Va., Coal Research Bureau Report No. 49 (1969).

1103 Wilson, E. B., and Humphreys, K. K., "A Cost Study of Power Plant Corrosion Control Methods", West Virginia Univ., Morgantown, W. Va., Coal Research Bureau Report No. 48 (1969).

1104 Muter, R. B., and Cockrell, C. F., "Application of Thermogravimetric Analysis to a Study of the Degree of Carbonation and Emulsion Addition During Agglomerate Flotation of Limestone Modified Flyash", West Virgina Univ., Morgantown, W. Va., Coal Research Bureau Report No. 54 (1970).

1105 Humphreys, K. K., and Lawrence, W. F., "Production of Mineral Wood Insulating Fibers from Coal Ash Slag and Other Coal Derived Waste Materials", West Virginia Univ., Morgantown, W. Va., Coal Research Bureau Report No. 53 (1970).

1106 Matkin, J. H., "Determination of Aerosol Size and Velocity by Holography and Steam-Water Critical Flow", Ph.D. Thesis, Washington University (1968).

1107 Lilienfeld, P., "β-Absorption-Impactor Aerosol Mass Monitor", GCA Technology Division, Bedford, Mass., Presented at American Industrial Hygiene Assoc. Conference, Detroit, Mich. (May 1970).

1108 Jech, C., "Utilization of Radioisotopes and Their Radiation in Aerosology", Proc. First National Conf. on Aerosols, Czechoslovak Academy of Sciences, Prague, p. 413-419 (1965).

1109 Sinclair, D., "Measurement of Average Particle Size in Aerosols by Light-Scattering", Paper no. 55-APC-10, ASME Comm. on Air Pollution Controls, 1st Int. Congress on Air Pollution, N.Y. (Mar 1-2, 1955).

1110 Gucker, F. T., "Instrumental Methods of Measuring Mass Concentration and Particulate Concentration in Aerosols", Proc. U.S. Technical Conference on Air Poll., Chap. 75.

1111 Sehmel, G. A., "Aerosols Deposition from Turbulent Air-Streams in Vertical Conduits", Battelle Memorial Inst., Richland, Va., Clearinghouse No. BNWL-578 (Mar 1968).

1112 Anon, "The Electric Utility Industry", Air Pollution Control Ass'n. Technical Manual no. 4, APCA, Pittsburgh, Pa. (Sep 1968).

1113 Anon, "Air Particulate Tape Sampler", Pollution Equipment News (Dec 1969).

1114 Masuda, S., "The Influence of Temperature and Moisture on the Electrical Conductivity of High Insulating Dusts", Staub-Reinhalt der Luft (Engl. Trans.), V. 25, p. 175-179 (May 1965), Clearinghouse No. BISI 4759.

1115 Lee, R. E., Jr., and Flesch, J.P., "A Gravimetric Method for Determining the Size Distribution of Particulates Suspended in Air", preprint Air Poll. Cont. Ass'n, 15 p., 1969, presented at the 62nd APCA Annual Meeting, New York, paper 69-125 (June 1969).

1116 Anon, "Flue-Gas Desulfurization Process to be Developed", Oil and Gas Journal, V. 68, no. 2, p. 72 (Jan 1970).

1117 Benarie, M., and Bodin, D., "Mise au Point et Essais d'Utilisation d'un Appareil Continu Pour la Mesure de Poussieres par Absorption de Rayons Beta", Pollution Atmospherique, no. 35, p. 147-155 (Jul-Sep 1967).

1118 DuBois, E., and Lutz, M., "Experimental Study of an Aerosol Size Selector", Assessment Airborne Radioactivity, Proc. Symp.Vienna, p. 379-392 (1967).

1119 Stober, W., "Design and Performance of a Size-Separating Aerosol Centrifuge Facilitating Particle-Size Spectrometry in the Submicron Range", Assessment Airborne Radioactivity, Proc. Symp., Vienna, p. 393-404 (1967).

1120 Raabe, O. G., "Calibration and Use of the Goetz Aerosol Spectrometer", Assessment of Airborne Radioactivity, Proc. Symp., Vienna, p. 417-431 (1967).

1121 Shalmon, E., and Donagi, A., "Sizing of Atmospheric Aerosols by Light and Electron Microscopy", Assessment Airborne Radioactivity, Proc. Symp., Vienna, p. 335-348 (1967).

1122 Lips, A., and Levine, S., "Light Scattering by Two Spherical Rayleigh Particles over All Orientations", Journal of Colloid & Interface Science, V. 33, no. 3, p. 455-463 (Jul 1970).

1123 Winkel, A., "On a New Dust Measuring Method", Staub-Reinhalt der Luft, V. 19, p. 253-255 (Jul 1959).

1124 Owen, P. R., "Dust Deposition from a Turbulent Airstream", Int. J. of Air Poll., V. 3, p. 8-25 (1961).

1125 Shale, C. C., Simpson, D. G., and Lewis, P.S., "Removal of Sulfur and Nitrogen Oxides from Stack Gases by Ammonia", paper presented at American Institute of Chemical Engineering, 62nd Annual Meeting, Washington, D. C., Paper 13B (Nov 16-20 1969).

1126 Dave, J. V., "Effect of Coarseness of the Integration Increment on the Calculation of the Radiation Scattered by Polydispersed Aerosols", Applied Optics, V. 8, no. 6, p. 1161-1167 (Jun 1969).

1127 DeBlois, R. W., and Bean, C. P., "Counting and Sizing of Submicron Particles by the Resistive Pulse Technique", Review of Scientific Instruments, V. 41, no. 7, p. 909-916 (Jul 1970).

1128 Moroz, W. J., Withstandley, V. D., and Anderson, G. W., "A Portable Counter and Size Analyzer for Airborne Dust", Review of Scientific Instruments, V. 41, no. 7, p. 978-983 (Jul 1970).

1129 Shaw, M., "Electrochemical Transducers for Air Pollution Monitoring", paper presented at Am. Chem., Soc., 158th Natl. Meeting, Div. Water Air Waste Chem., New York 1969. Preprint Am. Chem. Soc., Pittsburgh, Pa., Div. Water Air Waste Chem., 4 p. (1969).

1130 Hemeon, W. C., and Haines, G. F., Jr., "The Magnitude of Errors in Stack Dust Sampling, Air Repair, V. 4, no. 3, p. 159-164 (1954).

1131 Goadby, S. C., and Stephens, J. F., "Determination of Sulphur in Fly-Ash by X-ray Emission Spectroscopy", Fuel, V. 46, no. 1, p. 19-24 (Jan 1967).

1132 Taylor, F. R., Tomaras, Z. G., and Scott, W. E., "A Survey of Emissions from Residential Oil-Fired Heating Units", Scott Research Labs., Inc., Parkasie, Pa. SRL Proj. 1009c, 40 p (Mar 1963).

1133 Skala, G. F., "A New Instrument for the Continuous Measurement of Condensation Nuclei", Analytical Chemistry, V. 35, p. 702 (1963).

1134 Jacobs, G. B., and Snowman, L. R., "Laser Techniques for Air Pollution Measurement", IEE - Journal of Quantum Electronics, V. QE-3, no. 11, p. 603-5 (Nov 1967).

1135 O'Mara, R., and Flodin, C. R., "Controlling Dust and Fumes", Chemical Engineering, V. 65, no. 9, p. 139-142 (1958).

1136 Barrett, R. E., and Hazard, H. R., "Problems in Flue-Gas Temperature Measurements", ASHRAE Journal, V. 7, no. 1, p. 88-93,104 (Jan 1965).

1137 Quon, J. E., Tebbens, B. D., and Thomas, J. F., "Combustion Nuclei, An Index for Classifying Gaseous Hydrocarbon Fuels", Industrial & Engineering Chemistry, V. 53, p. 235-238 (Mar 1961).

1138 Hagerty, G. J., Jr., "Practical Instrumentation for Measuring Stack Emissions", Instrum. in Power Industry, V. 12, Proc. 12th Int'l. Symp. ISA, Philadelphia, Pa. (May 19-21 1969).

1139 Boyce, M. P., and Blick, E. F., "Fluid Flow Phenomena in Dusty Air", ASME - Paper 69-WA/FE-24, for meeting (Nov 16-20 1969).

1140 Jimeson, R. M., and Grout, J. M., "Solvent Refined Coal: Its Merits and Market Potential", Preprint Am. Inst. of Mining, Metallurgical and Petroleum Eng., New York, N.Y., 22 p. 1969. (Presented at AIME Annual Meeting, Washington, D. C. Feb. 16-20, 1969).

1141 Ullrich, O.A., "Size Analysis of Fine Particles and Results Obtained with an Electrical Sensing-Zone Particle Analyzer", Instr. Soc. Am., Conf. Preprint No. 40-NY60 for Fall Instrument-Automation Conf. and Exhibit, N.Y., N.Y. (Sep 26-30 1960).

1142 Yoder, J. D., and Silverman, L., "Influence of Turbulence on Aerosol Agglomeration and Deposition in a Pipe", 60th Annual APCA Meeting, Paper No. 67-33, Cleveland, Ohio (Jun 1967).

1143 Pilipowskyj, S., Weinman, J. A., Clemesha, B. R., Kent, G. S., and Wright, R. W., "Investigation of the Stratospheric Aerosol by Infrared and Lidar Techniques", Journal of Geophysical Research, V. 73, no. 24, p. 7553-7560 (Dec 1968).

1144 Gleason, G. I., Taylor, J. D., and Tabern, D. L., "Absolute Beta Counting at Defined Geometries", Nucleonics, V. 8, no. 5, p. 12-21 (1951).

1145 Thompson, B. J., "A New Method of Measuring Particle Size by Diffraction Techniques", Japan Journal of Applied Physics, Suppl. 14, p. 302-307 (1965).

1146 Danielson, J. A., "Air Pollution Engineering Manual", Public Health Service, Cincinnati, Ohio, Clearinghouse No. PB 190 243 (1967).

1147 Lee, Y. N., and Soo, S. L., "A Study of Jets of Electrically Charged Suspensions", Environmental Science and Technology, V. 4, no. 8, p. 678-685 (Aug 1970).

1148 Levy, A., Merryman, E. L., and Reid, W. T., "Mechanisms of Formation of Sulfur Oxides in Combustion", Environmental Science and Technology, V. 4, no. 8, p. 653-662 (Aug 1970).

1149 Iddings, F. A., "Nuclear Methods in Air and Water Pollution Analysis", Environmental Science and Technology, V. 3, no. 2, p. 132-140 (Feb 1969).

1150 Inaba, H., Kobayashi, T., Ichimura, T., Morihisa, M., and Taira, K., "Measurement of Propagation Characteristics of Optical Beams in the Atmosphere and Analysis of Returned Echo Signals Using Laser Radar Systems with A-Scope Representation", Electronics & Communications in Japan, V. 51, no. 9, p. 45-52 (Sep 1968).

1151 Luykx, F. F., Van der Stricht, E. A., "Symposium on Instruments and Techniques for the Assessment of Airborne Radioactivity in Nuclear Operations", Nuclear Safety, V. 10, no. 1, p. 54-62 (Jan-Feb 1969).

1152 Monaghan, M. T., and McGrath, I.A., "The Influence of Flue Gas Recirculation on the Combustion of Fuel Oil", Inst. Petroleum Journal, V. 55, no. 545, p. 302-321 (Sep 1969).

1153 Skinner, C. F., "Properties of Airborne Pollutants", Plant Engineering, V. 23, no. 25, p. 56-58 (Dec 1969).

1154 Kanter, C. V., Lunche, R. G., and Fudurich, A. P., "Techniques of Testing for Air Contaminants from Combustion Sources", APCA Journal, V. 6, no. 4, p. 191-199 (Feb 1957).

1155 Ryley, D. J., "Wet Stream Property Measurements: Current Problems: A Review", Int. J. of Mech. Sciences, V. 8, p. 581-589 (1966).

1156 Mitchell, C. A., and Silverman, L., "The Boundary Layer Diluter - a New Gas and Particulate Calibration Device", Paper presented to New England Section of the Air Pollution Control Association at Providence, Rhode Island (Apr 1963).

1157 Lynam, D. R., Pierce, J.O., and Cholak, J., "Calibration of the High-Volume Air Sampler", American Industrial Hygiene Assoc. Journal, V. 30, no. 1, p. 83-88 (Jan-Feb 1969).

1158 Hariharan, T. A., "An Airborne Polarimeter for Atmospheric Radiation Studies", Journal of Scientific Instruments, Journal of Physics E, Ser. 2, V. 2, no. 1, p. 10-12 (Jan 1969).

1159 Pretorius, R., and Wainerdi, R. E., "Nuclear Activation Analysis for Ultra-Sensitive Determinations of Environmental Pollutants", South African Medical Journal, p. 169-171 (Feb 1970).

1160 Hanst, P. L., "Infrared Spectroscopy and Infrared Lasers in Air Pollution Research and Monitoring", Applied Spectro. V. 24, no. 2, p. 161-174 (Mar-Apr 1970).

1161 Irani, R. R., and Kaelble, E. F., "Particle Size Distribution Measurements Below Five Microns", Analytical Chemistry, V. 33, no. 9, p. 1168-1170 (Aug 1961).

1162 Boudreau, R. D., "On the Use of Ultraviolet Lidar for Observing Atmospheric Constituents by Raman Scattering", Journal of Applied Meteorology, V. 9, p. 316-317 (Apr 1970).

1163 Duzy, A. F., "American Coal Characteristics and Their Effects on the Design of Steam Generating Units", Preprint, Am. Soc. of Mech. Engineers, New York, 1959 (Presented at ASME Annual Meeting, Atlantic City, N.J., Paper 59-A242, Nov 29 - Dec 4 1959).

1164 O'Donnell, H., Montgomery, T. L., and Corn, M., "Routine Assessment of the Particle Size-Weight Distribution of Urban Aerosols", Atmos. Environment, V. 4, p. 1-7 (1970).

1165 Rich, T. A., "Characteristics of Airborne Particles", ASME Paper 57SA56, for meeting June 9-13, 1957, 9 p., Publ. in: J. Eng. Power, (Jan 1959).

1166 Zimon, A. D., and Lazarev, K. A., "Adhesion of Particles from an Air Stream on an Obstacle; Dependence of Particle Adhesion on the Velocity of Air Stream", Colloid Journal of USSR, V. 31, no. 1, p. 47-49 (Jan-Feb 1969).

1167 Schwendiman, L. C., and Postma, A.K., "Turbulent Deposition in Sampling Lines", in: Seventh AEC Air Cleaning Conference, Brookhaven National Lab., Oct. 10-12,1961, Clearinghouse No. TID 7627, p. 127-136 (Mar 1962).

1168 Anon, "AEC/NASA Symposium on Contamination Control, Current and Advanced Concepts in Instrumentation and Automation", Albuquerque, N. M., Sep 12-14, 1967, Clearinghouse No. SC-M-68-94 (1967).

1169 Rotheram, M. A. "Laboratory Contaminant Sensor", Perkin-Elmer Corporation, Pomona, Calif., Clearinghouse No. N 68-23461, 2 Vol (Mar 1968).

1170 Goldberg, M. A., "The Theory of a Turbidimetric Back-Scattering Installation", U. S. Army Mobility Equipment Research and Development, Fort Belvoir, Va., Clearinghouse No. AD 680 766 (Jan 1969).

1171 Fiocco, G., "Investigations of Dust in the Upper Atmosphere by Optical Radar", Mass. Inst. of Technology, Cambridge, Mass., Clearinghouse No. N69-15833 (Nov 1968).

1172 Bateman, J. B., Weneck, E.J., and Eshler, D. C., "Determination of Particle Size and Concentration from Spectrophotometric Transmission", Journal of Colloid Science, V. 14, p. 308-329 (Jun 1959).

1173 Sehmel, G. A., "Particle Deposition from Turbulent Air Flow", Journal of Geophysical Research, V. 75, no. 9, p. 1766-1781 (Mar 1970).

1174 Collis, R. T. H., and Oblanas, J. W., "Lidar Observations of Debris Clouds from Nuclear Cratering Detonations", Stanford Research Inst., Menlo Park, Calif., Clearinghouse No. UCRL-13360 (Aug 1968).

1175 Wells, A. C., and Chamberlain, A. C., "Transport of Small Particles to Vertical Surfaces", British Journal of Applied Physics, V. 18, p. 1793-1799 (1967).

1176 Davies, C. N., "The Rate of Deposition of Aerosol Particles for Turbulent Flow Through Ducts", Annals Occupation Hygiene, V. 8, p. 239-245 (1965).

1177 Raabe, O. G., "A Study of the Absorption of Radon Daughters to Some Submicron Polydisperse Aerosols and to Some Natural Aerosols", Ph.D. Thesis, Univ. of Rochester, New York (1966).

1178 Jackson, P. J., and Raask, E., "A Probe for Studying the Deposition of Solid Material from Flue Gas at High Temperatures", Journal Inst. of Fuel, V. 34, p. 275-280 (Jul 1961).

1179 Salkowski, M., "Prototype Fly Ash Monitor for Incinerator Stacks", Final Report, Apr 1963-Jul 1964, IIT Research Inst., Chicago, Ill, 2 Vol. (Jul 1964).

1180 O'Konski, C. T., and Doyle, J., "Light-Scattering Studies in Aerosols With a New Counter-Photometer", Analytical Chemistry, V. 27, p. 694-701 (May 1955).

1181 Penndorf, R. B., "An Approximation Method to the Mie Theory for Collodial Spheres", J. Phys. Chem., V. 62, p. 1537-1542 (Dec 1958).

1182 Johnson, I., and LaMer, V. K., "The Determination of the Particle Size of Monodispersed Systems by the Scattering of Light", Amer. Chem. Soc. J., V. 69, p. 1184-1192 (1947).

1183 Heller, W., "Theoretical Investigations on the Light Scattering of Spheres. XV. The Wavelength Exponents at Small α Values", J. Chem. Phys., V. 40, p. 2700-2705 (1964).

1184 Heller, W., Bhatnagar, H. L., and Nakagaki, M., "Theoretical Investigations on the Light-Scattering of Spheres. XIII. The Wavelength Exponent of Differential Turbidity Spectra", J. Chem. Phys., V. 36, p. 1163-1170 (1962).

1185 Dezelic, G., Dezelic, N., and Tezak, B., "A Simple Method for Particle Size Determination by Turbidity Measurement", J. Coll. Sci., V. 18, p. 888-892 (1963).

1186 Barnes, M. D., and LaMer, V. K., "Monodispersed Hydrophobic Colloidial Dispersions and Light Scattering Properties, II. Total Scattering from Transmittance as a Basis for the Calculation of Particle Size and Concentration", J. Coll. Sci., V. 1, p. 79-91 (1946).

1187 Leemhorst, J. W., "Direct Measurement of Particulate Mass and Humidity", Contamination Control, p. 11-14 (Jul-Aug 1970).

1188 Schnitzler, H., "Untersuchungen uber die Eignung Registrierender Gerate zur Messungdes Staubgehaltes in Abhasen", Gesundheit-Ingenieur, V. 10, p. 307-309 (Jan 1970).

1189 Schnitzler, H., Maier, O., and Jander, K., "Messtand fur die Prufung und Kalibrierung von Registrierenden Staub - und Gasmessgeraten in einem Steinkohlengefeuerten Kraftwerk", SchrReihe Ver. Wass. - Boden Lufthyg. Berlin-Dahlem, V. 33, Stuttgart (1970).

1190 Mitchell, R. I., and Engdahl, R. B., "A Survey for Improved Methods for the Measurement of Particulate Concentration in Flowing Gas Streams", Battelle Memorial Institute, Columbus, Ohio (Mar 1963).

1191 DeVore, J. R., Weneck, E. J., and Eshler, D. C., "Determination of Particle Size and Concentration from Spectrophotometric Transmission", J. Coll. Sci., V. 14 (1958).

1192 Gucker, F. T., and Rose, D. G., J. Appl. Phys. Suppl. 3, (1954).

1193 Gucker, F. T., and Rose, D. G., Proc. Third Natl. Air Pollution Symp. (1955).

1194 Gucker, F. T., Proc. Ind. Instr. Conf., p. 284 (1956).

1195 Fowles, F. R., Introduction to Modern Optics, Holt, Rinehart, and Winston, Inc., New York (1968).

1196 Anon, "Model 177 Holographic Camera", Optics Technology, Inc., 901 California Ave., Palo Alto, Calif. 94304.

1197 Reynolds, G. O., and DeVelis, J. B., Theory and Applications of Holography, Addison-Wesley, Reading, Mass. (1967).

1198 Anon, Stat Volt Company, "Holographic Particle Size Determination Literature", 1130 Channel Drive, Santa Barbara, Calif.

1199 Newton, R. G., *Scattering Theory of Waves and Particles*, McGraw Hill (1966).

1200 Penndorf, R. B., "New Tables of Mie Scattering Functions for Spherical Particles, Part 6: Total Mie Scattering Coefficients for Real Refractive Indexes", *Geophysical Research Papers No. 45*, Air Force Cambridge Research Center, Bedford, Mass (1957).

1201 Van de Hulst, H. C., *Light Scattering by Small Particles*, Wiley (1957).

1202 Kenyon, A. S., "Higher Order Tyndall Spectra in Monodispersed Sulfur Sols", *Trans. N.Y. Acad. Sci*. (1962).

1203 LaMer, V.K., and Sinclair, D., "Verification of the Mie Theory", OSRD Rep. No. 1857 and 944, Office of Publ. Board, U.S. Dept. of Comm., Washington, D. C. (1943).

1204 Cole, J. E., III, Dobbins, R. A., and Semerjian, H., "Time-Resolved Measurement of Droplet Size and Concentration in Cloud Chambers", to appear in *J. Appl. Met.* (1970).

1205 Evans, R. D., *The Atomic Nucleus*, McGraw-Hill Book Co., Inc., N.Y., p. 628 (1955).

1206 Hart, H., "Radioactive Isotopes in Industrial Measuring Technology", *VEB Verlag Technik*, Berlin (1962).

1207 Kaelble, E. F., ed., *Handbook of X-rays,* McGraw-Hill Book Company (1967).

1208 Lapp, R. E., and Andrews, H. L., *Nuclear Radiation Physics*, Prentice Hall, Inc. (1948).

1209 Shumilovskii, N. N., and Milttsen, L. V., *Radioactive Isotopes in Instrumentation and Control*, The MacMillan Co. (1964).

1210 Randall, L. M., and Keller, J. D., "Electro-Optical Aerosol Counter Inst.", AIHA Conf., Houston, Texas (1955).

1211 Davies, C. N., ed. *Aerosol Science*, Academic Press (1966).

1212 Born, M., and Wolf, E., *Principles of Optics*, Pergamon Press (1964).

1213 Hodkinson, J. R., "The Physical Basis of Dust Measurement by Light Scattering", *Aerosols: Physical Chemistry and Application*, p. 181-194, Publishing House of the Czechoslovak Academy of Sciences, K. Spurny, Ed. (1965).

1214 Kerker, M., Electromagnetic Scattering, Pergamon Press (1963).

1215 Kerker, M., The Scattering of Light and Other Electromagnetic Radiation, Academic Press (1969).

1216 Green, H. L., and Lane, W. R., Particulate Clouds: Dusts, Smokes and Mists, E. and F. N. Spon Ltd., London (1964).

1217 Curtis, J. J., "An Evaluation of Two Large Volume Air-Sampling Devices", Dept. of the Army, Fort Detrick, Md., Clearinghouse No. AD 848 570 (Jan 1969).

1218 Dianov, D. B., Podolskii, A. A., and Turubarow, V. I., "Vibration of Aerosol Particles in an Acoustic Field", Kolloidnyi Zhurnal, V. 29, p. 69-74 (Jan-Feb 1967).

1219 Altshuller, A. P., "Instrumentation for Monitoring Air Pollutants", presented at ISA Analysis Div. Symp., Philadelphia, Pa. (May 1968).

1220 Denisov, A. S., Podolskii, A. A., and Turubarov, V. I., "Entrainment of Aerosol Particles in an Acoustic Field at Reynolds Numbers $R < 1$", Soviet Physics - Acoustics, V. 11, no. 1, p. 92-93 (Jul-Sep 1965).

1221 Sauerbrey, G. Z., "Verwendung von Schwing-quarzen sur Wagung dunner Schichten und zur Mikrowagung", Seits. Phys., V. 155, p. 206 (1959).

1222 Olin, J. G., Sem, G. J., and Christenson, D. L., "Piezoelectric/Electrostatic Aerosol Mass Concentration Monitor", Presented at Amer. Ind. Hyg. Assoc. Annual Conference, Detroit, Mich., (May 11-15 1970).

1223 Chuan, R. L., "An Instrument for the Direct Measurement of Particulate Mass", Aerosol Science, V. 1, p. 111-114 (1970).

1224 Holzhey, J., and Demmrich, H. "Ein radiometrisches Gerat zur kontinulerlichen Kontrolle des Gichtstaubanfalls", Neue Hutte, V. 14, p. 198-201 (Apr 1969).

1225 Raynor, G. S., "Variation in Entrance Efficiency of a Filter Sampler with Air Speed, Flow Rate, Angle and Particle Size", Amer. Ind. Hygiene Assoc. Journal, p. 294-304 (May-Jun 1970).

1226 Dobbins, R. A., and Strand, L. D., "A Comparison of Two Methods of Measuring Particle Size of Al_2O_3 produced by a Small Rocket Motor", AIAA Journal, V. 8, no. 9, p. 1544 - 1550 (Sep 1970).

1227 Asset, G., Kimball, D., and Hoff, M., "Small-Particle Collection Efficiency of Vertical Cylinders in Flows of Low-Intensity Turbulence", American Industrial Hygiene Association Journal, p. 331-334 (May-Jun 1970).

1228 Gast, T., "Akustische Ruckkopplung als Hilfsmittel bei der Bestimmung von Staubkonzentrationen mit Hilfe eines Schwingenden Bandes", Staub-Reinhalt der Luft, V. 30, no. 6, p. 235-238 (Jun 1970)

1229 Vitol, V., "Theoretical Limits of Errors Due to Anisokinetic Sampling of Particulate Matter" APCA Journal, p. 79-84 (Feb 1966).

1230 Crosse, P. A. E., Lucas, D. H., and Snowsill, W. L., "The Measurement of Dust Nuisance Emitted by Chimneys", Central Electricity Research Laboratories, p. 212-224 (Nov 1960).

1231 Falgout, D., Walter C. McCrone Associates, Inc., Chicago, Illinois, unpublished work (1969).

1232 Barnes, M. D., Kenyon, A. S., Zaiser, E. M., and LaMer, V. K., "Monodispersed Sulfur Sols. IV. Comparison of the Particle Radius Determined by Transmittance and by the Angular Positions of Higher Order Tyndall Spectra from the Mie Theory", Journal of Colloid Sciences, v. 2, p. 349-359 (1947).

1233 Bol, J., Gebhart, J., Roth, C., and Wurzbacher, G., "Analysis of Colloidal Air and Water Pollution by Light Scattering", Battell Institut, Frankfurt (1969).

1234 Johnson, I., and LaMer, V. K., "Particle Size of Colloidal Sulfur by Light Scattering", Journal of the American Chemical Society, V. 69, p. 1184-1192 (1947).

1235 Maron, S. H., and Elder, M. E., "Determination of Latex Particle Size by Light Scattering, I. Minimum Intensity Method", Journal of Colloid Science, V. 18, p. 107-118 (1963).

1236 Maron, S. H., Pierce, P. E., and Elder, M. E., "Determination of Latex Particle Size by Light Scattering, III. Minima and Maxima in Angular Dependence of Intensity", Journal of Colloid Science, V. 18, p. 391-399 (1963).

1237 Sloan, C. K., "Angular Dependence Light Scattering, Characterization of Disperse Systems Containing Particles 0.1 to 100 Microns in Radius", Paper Presented at 125th Meeting of American Chemical Society, St. Louis, (Mar 24 - Apr 1 1954).

1238 Sloan, C. K., "Angular Dependence Light-Scattering Studies of the Aging of Precipitators", Journal of Physical Chemistry, V. 59, p. 834-840 (1955).

1239 Thomson, W. T., Mechanical Vibrations, 2nd Ed., Prentice-Hall, Inc., Englewood Cliffs, N.J. (1953).

1240 Gould, G., "Formation of Air Pollutants", Power, p. 86 (Aug 1960).

1241 Negherbon, W. O., "Sulfur Dioxide, Sulfur Trioxide, Sulfuric Acid and Fly Ash: Their Nature and Their Role in Air Pollution", EEI Research Project RP62, (Jun 1966).

1242 Halliday, E. C., "Measurement of the Rise of Hot Plumes", Atmospheric Environment, Vol. 2, p. 509-516 (1968).

1243 Pilat, M. J., and Ensor, D. S., "Plume Opacity and Particulate Mass Concentration", Atmospheric Environment, V. 4, p. 163-173 (1970).

1244 Paulson, C. A. J., and Ramsden, A.R., "Some Microscopic Features of Fly-Ash Particles and Their Significance in Relation to Electrostatic Precipitation", Atmospheric Environment, V. 4, p. 175-185 (1970).

1245 Rae, J. B., and Garland, J. A., "A Stablized Integrating Nephelometer for Visibility Studies", Atmospheric Environment, V. 4, p. 219-223 (1970).

1246 Montgomery, T.L., and Corn, M., "Aerosol Deposition in a Pipe with Turbulent Airflow", Aerosol Science, V. 1, p. 185-213 (1970).

1247 Huang, C. M., Kerker, M., and Matijevic, E., "The Effect of Brownian Coagulation, Gradient Coagulation, Turbulent Coagulation and Wall Losses upon the Particle Size Distribution of an Aerosol". Journal of Colloid and Interface Science, V. 33, no. 4, (Aug 1970).

1248 Benarie, M., and Quetier, J. P., "Etude D'une Methode Microdynamometrique Pour a Mesure de la Concentration des Poussieres", Aerosol Science, V. 1, p. 77-109 (1970).

1249 Prochazka, R., "Neueste Entwicklung des auf Kontaktelektrischer Basis beruhenden Staubgehaltmessgerates Konitest", Staub-Reinhalt der Luft, V. 24, p. 353-359 (Sep 1964).

1250 Stratton, J. A., Electromagnetic Theory, McGraw Hill (1941).

1251 Jefferis, G. C., and Sensenbaugh, J. D., "Effect of Operating Variables from a Modern Power Station Boiler", ASME, (Oct 1959).

1252 Cross, F.L., Jr., and Frederick, B. H., Jrs., "Understanding Source Testing", Pollution Engineering, V. 2, no. 5, p. 35-36 (1970).

1253 O'Konski, C. T., Bitron, M. D., and Higuchi, W. I., ASTM Spec. Tech. Publ. No. 234 (1958).

1254 Duwel, L., "Comparative Investigations of Different Measuring Principles for Continuous Monitoring of Dust Emissions of Lignite Fired Steam-Boilers", Paper presented at Second International Clean Air Congress, Washington, D. C., Dec. 6 - 11, 1970.

1255 DeVore, J. R., and Pflund, A. H., "Optical Scattering by Dielectric Powders of Uniform Particle Size", J. Optical Society America, V. 56, p. 1351 (1947).

1256 Gnyp, A. W., Price, S. J. W., St. Pierre, C. C., and Steiner, J., "An Information Search for an Evaluation of Factors Affecting Stack Sampling", Industrial Research Institute, University of Windsor, (Sep 1970).

1257 Matthews, B. J., and Kemp, R. F., "Investigation of Scattered Light Holography of Aerosols and Data Reduction Techniques", TRW Systems Group, Redondo Beach, Calif.,TRW Report No. 14103-6002-R0-00 under NAPCA Contract CPA 70-4 (Nov 1970).

1258 Wajsfelner, R., "New Spectrometer for Charged Particles", Centre de'Etudes Nucleaires de Fontenay-aux-Roses, France (1970).

1259 Davies, C. N., "The Entry of Aerosols into Sampling Tubes and Heads", British J. Appl. Physics, V. 1, no. 2, p. 921-932 (1968).

1260 Feifel, E., "Staub als Ladungstrager", Radex-Rundschau, p. 904-917, (1957).

1261 Schmidt, K. G., "Staubfragen in der GieBereiindustrie", Giesserei, p. 173-180 (Apr 1963).

1262 Boning, P., "Theorie der Aufladungserscheinungen an Staub, Papier und Spinnstoffen", p. 655-658 (Oct 1962).

1263 Pilat, M. J., "Application of Gas-Aerosol Adsorption Data to the Selection of Air Quality Standards", paper presented at the Annual Meeting of the Air Pollution Control Assoc., St. Paul, Minn., Jun 23-27, 1968.

1264 O'Keeffe, A. E., "Needs in Electronic Instrumentation for Air-Pollution Analysis", IEEE Transactions on Geoscience Electronics, V. 8, no. 3, (Jul 1970).

1265 Beal, S. K., "The Effect of Particle Size Distribution upon Deposition", Materials-General, p. 568-569 (1970).

1266 Zimmerman, E., "The Measurement of Substance in Exhaust Gas", presented in a speech in the Kohlenstaubasschul of the Reichskohlenrates on Mar 6, 1930, Berlin.

1267 Corn, M., "Particle Size: Relationship to Collector Performance, Emission Standards and Ambient Air Quality", presented at Tech. Session 41 of the 2nd International Air Pollution Conference of the International Union of Air Pollution Prevention Associations, Washington, D. C., Dec. 10, 1970.

1268 Short, W., "Measurement of Grit and Dust Emission", ASME, New York, N.Y., p. 89-90, (May 1968).

1269 Smith, S. K., "Economics of Selecting Particulate Control Equipment", Pollution Engineering, p. 22-24 (Jan-Feb 1971).

1270 Norton, H. N., "Nuclear Radiation", Handbook of Transducers for Electronic Measuring Systems, Chapter 9, p. 387-413, Prentice-Hall, Inc. (1969).

1271 Bardswick, W. A., and White, F. T. M., "Trends in the Instrumental Assessment of Industrial Dustiness", Canadian Mining and Met. Bulletin, p. 1045-1051 (Oct 1969).

1272 Sinclair, D., "Effect of Convection and Turbulence on Diffusion of Small Aerosol Particles in Circular Tubes", Staub-Reinhalt der Luft, (Engl.Trans.), V. 29, no. 5, p. 13 - 15 (May 1969).

1273 Israel, G. W., "Investigations of Aerosol Beams", Staub-Reinhalt der Luft, (Engl. Trans.), V. 29, no. 5, p. 5 - 8 (May 1969).

1274 McGuire, T., and Noll, K. E., "Relationships Between Concentrations of Atmospheric Pollutants and Averaging Time", Paper Presented at 11th Conference Methods in Air Pollution and Industrial Hygiene Studies, Berkeley, Calif., Mar. 30, 31, and Apr 1, 1970.

1275 Whitby, K. T., and Liu, B. Y. H., "Atmospheric Aerosol Size Distribution", Paper Presented at 11th Conference Methods In Air Pollution and Industrial Hygiene Studies, Berkeley, Calif., Mar. 30, 31, and Apr 1, 1970.

1276 Whitby, K. T., and Liu, B. Y. H., "Atmospheric Particulate Data - What Does It Tell Us About Air Pollution?", Paper Presented at 11th Conference Methods in Air Pollution and Industrial Hygiene Studies, Berkeley, Calif., Mar. 30, 31, and Apr 1, 1970.

1277 Haberl, J. B., and Fusco, S. J., "Condensation Nuclei Counters: Theory and Principles of Operation", Paper Presented at 11th Conference Methods In Air Pollution and Industrial Hygiene Studies, Berkeley, Calif., Mar. 30, 31 and Apr 1, 1970.

1278 Spurny, K., and Fiser, J., "Bemerkung zur mikrogravimetrischen Bestimmung der Aerosolkonzentration mit Hilfe von Filtrationsmethoden", Staub-Reinhalt der Luft, V. 30, no. 6, p. 249-250 (Jun 1970).

1279 Matthews, B. J., and Kemp, R. F., "Holographic Determination of Injected Limestone Distribution in Unit 10 of the Shawnee Power Plant", TRW Systems Group, Redondo Beach, Calif. , TRW Report No. 14103-6001-R0-00 under NAPCA Contract CPA 70-4 (Jun 1970).

1280 Jaye, F. C., and Steiber, R. S., "Additional Testing of Von Brand Tape Sampler with Limestone in a Wind Tunnel", Dept. of Health, Education & Welfare, National Air Pollution Control Administration, Cincinnati, Ohio (Sep 1970).

1281 Smith, W. S., Martin, R. M., Durst, D. E., Hyland, R. G., Logan, T.J., and Hager, C. B., "Stack Gas Sampling Improved and Simplified with New Equipment", paper presented at the 60th Annual Meeting of the Air Pollution Control Association, Cleveland, Ohio (Jun 11 - 16, 1967).

1282 Jackson, M. R., and Lieberman, A., "Prototype Fly Ash Monitor for Incinerator Stacks", American Public Works Association, Report No. IITRI-C8088-5 (Feb. 1 - May 31, 1967).

1283 Langer, G., "Prototype Fly Ash Monitor for Incinerator Stacks", American Public Works Association, Report No. ARF C8015-1 (Apr 15 - Jun 15, 1963).

1284 Sisson, W., "Estimating Air Pollutants from Stacks", Nipak, Inc., Pryor, Okla.

1285 Paulus, H. J., and Peterson, C. M., "Urban Aerosol: Count Size Related to Meteorologic Data", School of Public Health, University of Minnesota, Minneapolis, Minn., Final Report (Nov 1969).

1286 Lieberman, A., and Allen, R. J., "Theoretical & Experimental Light Scattering Data for a Near Forward System", paper presented at American for Contamination Control, May 19, 20, 21, 22, 1969.

1287 Mednikov, E. P., "Absorption and Dispersion of Sound in Aerosols at Large Particle Velocity Amplitudes", *Soviet Physics-Acoustics*, V. 15, no. 4 (Apr-Jun 1970).

1288 Leighton, P. A., Perkins, W. A., Grinnell, S. W., and Webster, F. X., "The Fluorescent Particle Atmospheric Tracer", *Journal of Applied Meteorology*, V. 4, no. 3, pp. 334-348 (Jun 1965).

1289 Faith, W. L., "An Evaluation of Regulations for Control of Particulate Matter Emissions", paper presented at the 63rd Annual Meeting of the Air Pollution Control Association, St. Louis, Missouri, Jun 14 - 18, 1970.

1290 Sundaram, T. R., and Ludwig, G. R., "Simulation of Small-Scale Atmospheric Turbulence in a Laboratory Facility", paper presented at the Subsonic Aerodynamic Testing Association Meeting, Ottawa, May 14-15, 1970.

1291 Dreyhaupt, F. J., "Experiences with a Combined Tele-Lidar-Station for Controlling Emissions Day and Night During a Test-Operation", paper presented at the Second International Clean Air Congress of the International Union of Air Pollution Prevention Association, Washington, D. C., Dec. 6-11, 1970.

1292 Persson, G., "Swedish Emission Limits for Specific Sources of Air Pollution", paper presented at the Second International Clean Air Congress of the International Union of Air Pollution Prevention Association, Washington, D. C., Dec. 6-11, 1970.

1293 Busby, H. G. T., Whitehead, C., and Darby, K., "High Efficiency Precipitator Performance on Modern Power Stations Firing Fuel Oil and Low Sulphur Coals", paper presented at Second International Clean Air Congress of the International Union of Air Pollution Prevention Association, Washington,D. C., Dec. 6-11, 1970.

1294 Kurfurst, J., "Management of Air Pollution Control in Czechoslovakia", paper presented at the Second International Clean Air Congress of the International Union of Air Pollution Prevention Association, Washington, D.C., Dec. 6-11, 1970.

1295 Locklin, D. W., Weller, A. E., and Barrett, R. E., et al, "The Federal R & D Plan for Air-Pollution Control by Combustion-Process Modification", Battelle Memorial Institute, Columbus, Ohio, Final Report prepared under Cont. No. CPA-22-69-147 for Air Pollution Control Office, Environmental Protection Agency(Jan 11, 1971).

1296 Hidy, G. M., and Brock, J. R., "An Assessment of the Global Sources of Troposheric Aerosols", paper presented at the Second International Clean Air Congress of the International Union of Air Pollution Prevention Association, Washington, D. C., Dec. 6-11, 1970.

1297 Nicholson, W. J., Rohl, A., and Ferrand, E.F., "Asbestos Air Pollution In New York City", paper presented at the Second Inter-National Clean Air Congress of the International Union of Air Pollution Prevention Association, Washington, D. C., Dec. 6-11, 1970.

1298 Hariharan, T. A., "A Method For Remote Sensing of Particulates in The Atmosphere", paper presented at the Second International Clean Air Congress of the International Union of Air Pollution Prevention Association, Washington, D. C., Dec. 6-11, 1970.

1299 Knight, G., "A Simple Method for Determining Size Distribution of Airborne Dust by its Settling Velocity", paper presented at the American Industrial Hygiene Association Annual General Meeting, Detroit, Mich., May 19, 1970.

1300 Anon, "An Annotated Bibliography on Methods of Visibility Measurement", Office of Administration and Technical Services, Rockville, Maryland, Clearinghouse No. PB 188 652 (Sep 1969).

1301 Hemeon, W. C. L., Haines, G. F., and Ide, H. M., "Determination of Haze and Smoke Concentrations by Filter Paper Samplers", Air Repair, V. 3, no. 1, p. 22-28 (Aug 1953).

1302 Berg, Owe, T. G.,et al, "Investigation of the Force of Adhesion Between Powder Particles", Aerojet-General Corporation, Downey, Calif., Clearinghouse No. AD 671 010 (Mar 1963).

1303 Corcoran, J. F., "Replication of Fly-Ash Particles for Electron Microscopy", Journal Unknown.

1304 Zarfoss, J. R., "Ductwork Arrangement Criteria for Electrostatic Precipitators Without Model Study", APCA Journal, V. 20, no. 9, pp. 577-581 (Sep 1970).

1305 Ioos, E., and Emmerichs, M., "A New Sampling Probe for Dusts", Staub-Reinhalt. der Luft,(Engl. Trans.), v. 29, no. 10, pp. 26-27 (Oct 1969).

1306 Coenen, W., "A Simple Flow-Sensitive Arrangement with a Thermistor and Its Technical Application to Dust Measurement", Staub-Reinhalt der Luft, Engl Trans., V. 29, no. 11, pp. 16-22 (Nov 1969).

1307 Dalzell, W. H., Williams, G. C., and Hottel, H. C., "A Light-Scattering Method for Soot Concentration Measurements", Combustion and Flame, V. 14, pp. 161-170 (1970).

1308 Bicket, N. A., and Gary, G. A., "Mie Scattering: A Computer Program and an Atlas", George C. Marshall Space Flight Center, Alabama, Clearinghouse No. N 70 17291 (Sep 1969).

1309 Oeseburg, F., "A Literature Study About The Possible Use Of A Laser As A Light Source In A Particle Counter", Clearinghouse No. N70-16141 (1969).

1310 Brockhuas, A., and Friedrichs, K.H., "Die Messung partikelförmiger Immissionen", VDI-Berichte, V. 149, pp. 198-203 (1970).

1311 Brocke, W., "Rubabscheidung bei Ölfeuerungen", VDI-Berichte, V. 149, pp. 279-285 (1970).

1312 Dreyhaupt, F. J., "Mittel und Ziele behördlicher Emissionsüberwachung", VDI-Berichte, V. 149, pp. 33-40 (1970).

1313 Moore, W., "Radiation Sensitive Smoke Detecting Device", U.S. Patent No. 3,505,529 (Feb 1968).

1314 Enemark, R. B., et al, "Smoke Detector Including Porous Housing Means", U. S. Patent No. 3,497,303 (Jul 1967).

1315 Mammarella, L., "Aerosol Cascade Sampler", U. S. Patent No. 3,482,432 (Feb 1968).

1316 Payton, E. J., et al, "Optical Device for the Examination of Smoke and Dust Laden Gas", U.S. Patent No. 3,500,450 (Jun 1966).

1317 Astheimer, R. W., "Method of Remotely Monitoring Stack Effluent", U. S. Patent No. 3,517,190 (Dec 1967).

1318 Dunn, J. F., Jr., et al, "On the Design of an Instrument to Use Forward-Scattered Light to Detect Small Particles", Northwestern University, Boston, Mass., Clearinghouse No. AD 693 557 (Aug 1969).

1319 Schiager, K. J., Allen, T. M., Gerber, S. B., Kinsella, G. E., Krupka, F. J., and Reilly, D. W., "Improved Membrane-Filter Air-Sampling Methods for Environmental Control", Health Physics, V. 7, pp. 185-190 (1962).

1320 Huang, C.M., Kerker, M., Matijevic, E., and Cooke, D.D., "Aerosol Studies by Light Scattering. VII. Preparation and Particle-Size Distribution of Linolenic Acid Aerosols", Journal of Colloid and Interface Science, V. 33, no.2, pp. 244-254 (Jun 1970).

1321 Anon, "Improved N.C.B. Apparatus for Measuring Flue Gas Dust Concentrations", The Steam and Heating Engineer, pp. 12-15 (Feb 1970).

1322 Shannon, L. J., and Vandergrift, A. E., "Particulate Pollution and Its Control", MRI Quarterly, Published by Midwest Research Institute, Kansas City, Mo. (Winter 70-71).

1323 Morrow, N. L., Bertrand, R. R., and Hall, H. J., "Instrumentation Available for the Measurement of Particulates, Sulfur Dioxide and Nitrogen Oxides in the Ambient Atmosphere", Paper Presented at the National Meeting, American Institute of Chemical Engineers, Houston, Texas, Mar. 4, 1971.

1324 Hamilton, P. M., "The Application of a Pulsed-Light Rangefinder (Lidar) to the Study of Chimney Plumes", Phil. Trans. Roy. Soc. London, V. 265, pp. 153-172 (1969).

1325 Littlejohn, R. F., "Comment on Recent Papers, Particle Size Analysis", Journal Unknown.

1326 Hayes, E. I., and Scott, J. A., "An Automatic Photoelectric Condensation Nucleus-Counter", Proc. R.I.A, v. 68, sec. A, pp. 33-39 (Oct 1969).

1327 Flux, J. H., Smithson, D.J., and Smithson, R. N., "Simplified Dust Sampling Apparatus for Use in Iron and Steelworks", Journal of the Iron and Steel Institute, pp. 1188-1193 (Dec 1968).

1328 Anon, "Suspended Solids Monitor", American-Standard Research & Development Division, New Brunswick, N.J. (Oct 1970).

1329 Sundaram, T. R., Skinner, G. T., and Ludwig, G. R., "Simulation of Small-Scale Atmospheric Phenomena", Cornell Aeronautical Laboratory, Inc., Buffalo, N.Y., Final Technical Report Cal Report No. VC-2697-A-1 (Apr 1970).

1330 Romanek, W., Jackson, M. R., and Lieberman, A., "Prototype Fly Ash Monitor for Incinerator Stacks", IIT Research Institute, Chicago, Ill., Final Report, Phase III, No. IITRI-C8088-8, prepared for American Public Works Association (Sept 1968).

1331 Todd, W. F., Hagan, J. E., and Spaite, P. W., "Test Dust Preparation and Evaluation", Public Health Service, U. S. Department of Health, Education, and Welfare, Cincinnati, Ohio.

1332 Graham, A. L., and Hanna, T. H., "The Micro-Particle Classifier", Ceramic Age, (Sep 1962).

1333 Fuchs, N. A., "The Mechanics of Aerosols", Published by The MacMillian Company, New York, N.Y. (1964).

1334 Anon, "Threshold Limit Values of Airborne Contaminants for 1968", American Conference of Governmental Industrial Hygienists (1968).

1335 Lippmann, M., and Harris, W. B., "Size-Selective Samplers for Estimating Respirable Dust Concentrations", Health Phys., 8:155-163 (1962).

1336 Matthews, B. J., and Wuerker, R. F., "Measurement of Fine Particulate In Pollution Control", Paper Presented at SPIE Seminar in Depth, Holography '71, Society of Photo-Optical Instrumentation Engineers, Boston, Mass., Apr 14 - 15, 1971.

1337 Knight, G., and Lichti, K., "Comparison of Cyclone and Horizontal Elutriator Size Selectors", American Industrial Hygiene Association Journal, pp. 437-441 (Jul-Aug 1970).

1338 Patton, W. F., and Brink, J. A., Jr., "New Equipment and Techniques for Sampling Chemical Process Gases", Paper Presented at the 55th Annual Meeting of APCA, Chicago, Illinois, May 20-24, 1962.

1339 Ziesse, N. G., and Penney, G. W., "Some Effects of Particle Size on Measurements of Fine Airborne Particulates", Carnegie-Mellon University under ASHRAE RP-60 and RP-90. (1970).

1340 Marple, V. A., "A Fundamental Study of Inertial Impactors", Ph.D. Thesis, Dept. of Mechanical Engineering, University of Minnesota (Sep 1970).

1341 Dyment, J., "Use of a Goetz Aerosol Spectrometer for Measuring the Penetration of Aerosols Through Filters as a Function of Particle Size", Aerosol Science, Vol. 1, pp. 53-67 (1970).

1342 Khmelevtsov, S. S., "A Size-Separation Collector for Sampling Aerosols From Curvilinear Flow", Dept. of the Army, Ford Detrick, Frederick, Maryland, Clearinghouse No. AD 678 123 (Nov 1967).

1343 Redkin, J.N., "Properties of Atmospheric Aerosol Measured with a Centrifugal Spectrometer", Journal of Geophysical Research, Vol. 75, no. 18, (Jun 1970).

1344 Whitby, K.T., Husar, R., McFarland, A. R., and Tomaides, M., "Generation and Decay of Small Ions", University of Minnesota, Minneapolis, Minn., prepared for National Air Pollution Control Admin., under USPHS Research Grant No. AP 00136-08 (Jul 1969).

1345 Sehmel, G. A., "Complexities of Particle Deposition and Re-Entrainment in Turbulent Pipe Flow", Aerosol Science,V. 2, pp. 63 - 72 (1971).

1346 Kubie, G., "A Note on a Treatment of Impactor Data for Some Aerosols", Aerosol Science, V. 2. pp. 23 - 30 (1971).

1347 Ensor, D. S., and Waggoner, A. P., "Angular Truncation Error in the Integrating Nephelometer", Atmospheric Environment, V. 4, pp. 481-487 (1970).

1348 Gentilizza, M., Fugas, M., and Weber, K., "Application of Fluorimetry in Smoke Measurement", Atmospheric Environment, V. 5, pp. 103-109 (1971).

1349 McCrone, W. C., Draftz, R. G., and Delly, J. G., The Particle Atlas, Ann Arbor Science Publishers, Ann Arbor, Mich.(1967).

1350 Andersen, A. A., "Bacterial Aerosol Analyzer", U.S. Patent No. 3,001,914 (Sep 1961).

1351 Olin, J. G., Trautner, R. P., and Sem, G. J., "Air-Quality Monitoring of Particle Mass Concentration with a Piezoelectric Particle Microbalance", Paper No. 71-1, 64th Annual Meeting, Air Pollution Control Association, Atlantic City, N.J. (Jun - Jul 1971).

1352 King, W. H., Jr., "Using Quartz Crystals as Sorption Detectors, Parts 1 and 2, Research/Development, V. 20, no. 28, p. 28-34 (Apr 1969), and V. 20, no. 28, p. 28-33 (May 1969).